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California Regional Wind Energy Forecasting System Development Volume 4: California Wind Generation Research Dataset (CARD)

PIER FINAL PROJECT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By:
Electric Power Research Institute, Inc.

ELECTRIC POWER
RESEARCH INSTITUTE

September 2006
CEC-500-2006-089

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Contract No. 500-02-014
Work Authorization WA-111

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CITATIONS

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This document describes research sponsored by the Electric Power Research Institute and the California Energy Commission.

The publication is a corporate document that should be cited in the literature in the following manner:

California Regional Wind Energy Forecasting System Development, Volume 4: California Wind Generation Research Dataset (CARD), Electric Power Research Institute. Palo Alto, CA, and California Energy Commission, Sacramento, CA: 2006. 1013265.

REPORT SUMMARY

The rated capacity of wind generation in California is expected to grow rapidly in the future beyond the approximately 2100 megawatts in place at the end of 2005. The main drivers are the state's 20 percent renewable portfolio standard requirement in 2010 and the low cost of wind energy relative to other renewable energy sources.

As wind is an intermittent generation resource and weather changes can cause large and rapid changes in output, system operators will need accurate and robust wind energy forecasting systems in the future. In response to this need, the California Energy Commission (Energy Commission) and EPRI initiated the California Regional Wind Energy Forecasting System Development Project in 2003 to develop and test short- and intermediate-term (for example, next-hour and next-day) forecast algorithms with improved forecast accuracy relative to the results of a previous project completed in 2002.

Volume 4 of the final report presents the development and example applications of the California Wind Generation Research Dataset (CARD). Volumes 1, 2, and 3 present the executive summary of the research results and the detailed results of the research on short- and intermediate-term forecasting, high-resolution wind flow modeling over complex terrain, and wind tunnel modeling over the complex terrain at Altamont Pass.

Results and Findings

The CARD database provides simulated hourly wind speed, direction, power generation, ambient temperature, and other parameters over the one-year period July 1, 2004 through June 30, 2005. The data are provided at multiple elevations over two grids in Northern and Southern California with five-kilometer grid spacing. They were generated using atmospheric sensor data and coarse-resolution forecast model output data from the U.S. National Weather Service as input to a high-resolution physics-based atmospheric numerical model. The CARD database is available in electronic form by download from the Energy Commission website. The data can be extracted using two programs described in the report.

Challenges and Objectives

Electricity systems with significant intermittent wind capacity create a challenge to the system operator. Rapid changes of wind generation relative to load require rapid dispatching of generation and transmission resources to balance generation vs. load, regulate voltage and frequency, and maintain system performance within limits established by Control Performance Standards 1 and 2 (CPS1 and CPS2). This is especially true during periods when wind generation is fluctuating rapidly relative to system load, for example, during passage of thunderstorms and weather fronts. Wind energy forecasts can help the system operator anticipate rapid changes of

wind energy generation vs. load and make informed decisions. The overall project objectives are to develop and demonstrate the capabilities of wind energy forecasting technology for both same-day and longer-term forecasts.

Applications, Values, and Use

Potential applications of the CARD database include wind project development, wind power integration studies, wind energy forecasting system development and testing, and other uses. Potential high-value applications include the optimum placement of meteorological towers in and surrounding wind resource areas that minimize the error of next-hour and next-day wind energy forecasts that rely on real-time wind resource measurements. The potential value of high-accuracy forecasts in reduced system regulation and other costs is significant. For example, a recent study in New York state found that the value of wind forecasting in the state is $94 million.

EPRI Perspective

The one year of hourly wind speed, direction, power generation, and other data provided by the CARD database is an invaluable resource. The CARD data can be used by utilities, wind project developers, independent system operators, and others to facilitate evaluation the impact of adding large blocks of wind generation to the California electricity grid on system operations, specifically load following and reserve requirements and predicted hourly wind power ramp rates. In addition, it can also be used to optimize the development of an integrated wind energy forecasting system and network of real-time meteorological towers in the state. The results presented in this report and the companion volumes represent significant advances in both short-term and intermediate-term wind energy forecasting technology. It is important to continue research on wind energy forecasting in California both to implement the forecast algorithms to provide real-time forecasts to utility and CA ISO system operators and to complete the development and testing of accurate same-day and next-day forecast algorithms.

Approach

Researchers developed the California Wind Generation Research Dataset (CARD) to provide a resource for future study of wind energy generation and forecasting in California. To avoid proprietary data issues and problems created by differences in scale and accuracy associated with many available data sources, the decision was made that the database would consist of grid point data generated by a numerical model, the MASS-6 high-resolution physics-based atmospheric model. Therefore CARD does not contain proprietary data associated with any specific wind project or meteorological tower.

Keywords

Wind resource data, Wind power generation data, California, Mesoscale weather models

ABSTRACT

The rated capacity of wind generation in California is expected to grow rapidly in the future beyond the approximately 2100 MW in place at the end of 2005. The main drivers are the state's 20 percent renewable portfolio standard requirement in 2010 and the low cost of wind energy relative to other renewable energy sources.

As wind is an intermittent generation resource and weather changes can cause large and rapid changes in output, system operators will need accurate and robust wind energy forecasting systems in the future. In response to this need, the California Energy Commission (Energy Commission) and EPRI initiated the California Regional Wind Energy Forecasting System Development Project in 2003 to develop and test short- and intermediate-term (for example, next-hour and next-day) forecast algorithms with improved forecast accuracy relative to the results of a previous project completed in 2002.

Volume 4 of the final report describes the development and example applications of the California Wind Generation Research Dataset (CARD). Volumes 1, 2, and 3 present the executive summary of the research results and the detailed results of the research on short- and intermediate-term forecasting, high-resolution wind flow modeling over complex terrain, and wind tunnel modeling over the complex terrain at Altamont Pass.

The CARD dataset is a database of near-surface atmospheric parameters that can be used as a resource in future research and development activities in the wind energy community. To avoid proprietary data issues and problems created by differences in scale and accuracy associated with many available data sources, the decision was made that the database would consist of grid point data generated by a numerical model.

The CARD database was generated using Version 6 of the MASS model. The database consists of two-dimensional fields of selected variables at one-hour intervals from two 5-km grids centered over Northern and Southern California respectively. The model runs were initialized at 0000 Coordinated Universal Time (UTC) for each day of the period from July 2004 through June of 2005 and data for hours 9 to 32 of the runs were extracted and included in the database. The data are stored in separate set of directories for the Northern and Southern California grids. The data for each day of the period are stored within dated directories under the grid directories. The report describes and provides a user guide for two programs that extract data from the database, plus lists of the variables available in the database.

ACKNOWLEDGEMENTS

Several organizations and individuals contributed to and provided data and information for the California Regional Wind Energy Forecasting System Development Project addressed in this and other volumes of the final report. They include Dr. Dora Yen-Nakafuji and Michael Kane of the California Energy Commission; David Hawkins of the California Independent System Operator (CA ISO); Dr. Marc Schwartz of the National Renewable Energy Laboratory (NREL); Dr. Robert Farber of Southern California Edison (SCE); Cliff Murley of the Sacramento Municipal Utility District (SMUD); Mark Smith of FPL Energy; Julie Morris of PPM Energy; Rick Koebbe and Bob Szymanski of Pacific Winds, Inc./PowerWorks; Inc.; Ed Duggan and Jeremiah Sota of Oak Creek Energy Systems; Brian Ulberg, MDU Resources; John Zack, Kenneth T. Waight III, Pamela Barlow, Joe Nocera, and Dan Mead of AWS Truewind, LLC; Professor Bruce White and Dr. David Lubitz of the University of California at Davis; and Dr. Steve Chin of Lawrence Livermore National Laboratory (LLNL). The project was supported by the Public Interest Energy Research Program of the California Energy Commission.

CONTENTS

1 INTRODUCTION 1-1

Previous Energy Commission-EPRI Wind Energy Forecasting Project, 2001-2003 1-2

Current Regional Wind Energy Forecasting System Development Project, 2004-2005 1-2

Objectives and Scope 1-3

Project Participants 1-4

CARD Dataset Overview 1-4

Report Organization 1-5

2 CARD DATASET CREATION 2-1

Methodology 2-1

Mesoscale Atmospheric Simulation System Version 6 (MASS-6) 2-1

Nested Grids 2-1

Initialization of Simulations 2-2

CARD Dataset Contents 2-4

3 CARD DATASET STRUCTURE AND CONTENTS 3-1

Directory Structure 3-1

Dated Directories and Hourly Grid Point Data Files 3-2

ASTAT Directory and Summary Statistic Files 3-2

STATIC_DATA Directory and Terrain and Elevation Data Files 3-2

ASTAT Summary Statistics Files 3-2

PLOT* Hourly Data Files 3-7

4 CARD DATASET EXAMPLES 4-1

Mean Wind Speed 4-1

Mean Wind Power Density 4-1

Maximum Hourly Average Wind Speed 4-2

Maximum and Minimum Hourly Average Air Density 4-2

5 DATA EXTRACTION PROGRAMS **5-1**
EXTRACT_POINTSTATS Program 5-1
Overview 5-1
Execution Instructions 5-5
EXTRACT_TIMESERIES Program 5-7
Overview 5-7
Execution Instructions 5-7

6 SUMMARY **6-1**

7 REFERENCES **7-1**

LIST OF FIGURES

Figure 1-1 California Mean Wind Power Map at 50-m Elevation and 2005 Rated Capacity of Wind Generation at Principal Wind Resource Areas (California Energy Commission, 2006) 1-1

Figure 2-1 The geographical domain covered by the 100 X 80 matrix of 20 km grid cells used to produce the parent coarse grid MASS 6 simulations for the project (A Grid)........ 2-2

Figure 2-2 The Northern California geographical domain covered by the 80 X 80 matrix of 5-km grid cells used to produce the high-resolution MASS 6 simulations (B Grid)........ 2-3

Figure 2-3 The Southern California geographical domain covered by the 80 X 80 matrix of 5-km grid cells used to produce the high-resolution MASS 6 (C Grid).......................... 2-3

Figure 3-1 Directory structure of the CARD database; the shaded boxes denote directories. Names not enclosed in boxes are files. The numbers in parentheses indicate the number of files or directories in each database element. See text for explanation of directory and file names.. 3-1

Figure 4-1 The simulated mean 50-m AGL wind speed for the Northern California 5-km grid (Grid B) for the period July 2004 to June 2005, physics-based numerical forecast simulations using the MASS-6 atmospheric model 4-3

Figure 4-2 The simulated mean 50-m AGL wind speed for the Southern California 5-km grid (Grid C) for the period July 2004 to June 2005, physics-based numerical forecast simulations using the MASS-6 atmospheric model 4-3

Figure 4-3 The simulated mean 50-m AGL wind power density (watts/m2) for the Northern California grid (Grid B) for the one-year period July 2004 to June 2005, daily physics-based numerical forecast simulations using the MASS-6 atmospheric model 4-4

Figure 4-4 The simulated mean 50-m AGL wind power density (watts/m2) for the Southern California 5-km grid (Grid C) for the one-year period July 2004 to June 2005, daily physics-based numerical forecast simulations using the MASS-6 atmospheric model.. 4-4

Figure 4-5 The simulated maximum 50-m AGL hourly-average wind speed (m/s) for the Northern California 5-km grid (Grid B) and the period July 2004 to June 2005, physics-based numerical forecast simulations using the MASS-6 atmospheric model 4-5

Figure 4-6 The simulated maximum 50-m AGL hourly-average wind speed (m/s) for the Southern California 5-km grid (Grid C) and the period July 2004 to June 2005, physics-based numerical forecast simulations using the MASS-6 atmospheric model 4-5

Figure 4-7 The simulated maximum 50-m AGL hourly-average air density (kg/m3) for the Northern California 5 km grid (Grid B) and the period July 2004 to June 2005,

physics-based numerical forecast simulations using the MASS-6 atmospheric model 4-6
Figure 4-8 The simulated maximum 50-m AGL hourly-average air density (kg/m3) for the Southern California 5-km grid (Grid C) and the period July 2004 to June 2005, physics-based numerical forecast simulations using the MASS-6 atmospheric model 4-6
Figure 4-9 Simulated minimum 50-m AGL hourly average air density (kg/m3) for the Northern California 5-km grid (Grid B) and the period July 2004 to June 2005, physics-based numerical forecast simulations using the MASS-6 atmospheric model 4-7
Figure 4-10 Simulated minimum 50-m AGL hourly-average air density (kg/m3) for the Southern California 5-km grid (Grid C) and the period July 2004 to June 2005, physics-based numerical forecast simulations using the MASS-6 atmospheric model 4-7

LIST OF TABLES

Table 3-1 ASTAT File Contents...3-3
Table 3-2 Fields in the ASTAT files 3-4
Table 3-3 PLOT file contents. 3-8
Table 3-4 Fields in the hourly plot files 3-9
Table 5-1 Variables available to be extracted by the extract_pointstats program 5-1
Table 5-2 Example option file for the extract_pointstats program..5-6
Table 5-3 : Variables available to be extracted by extract_timeseries program 5-8
Table 5-4 Example option file for the extract_timeseries program...5-10

1 INTRODUCTION

California has good potential for developing new wind generation capacity beyond the approximately 2100 megawatts of rated capacity in place at the end of 2005 (American Wind Energy Association, 2006). California's Renewable Portfolio Standard, which calls for 20% renewables in the generation mix by the end of 2010, will result in a large increase of the installed wind capacity in the state. Most of the current capacity is located in the five principal wind resource areas of the state (Solano, Altamont, Pacheco, Tehachapi, and San Gorgonio), shown in Figure 1-1. The new capacity is expected to be installed in these and other promising California wind resource areas in Northern and Southern California.

Rated Capacity – 2005 (MW)	
Solano County	240.8
Altamont Pass	548.3
Pacheco Pass	16.0
Tehachapi Pass	667.1
San Gorgonio Pass	616.6
Others	52.8
TOTAL	2141.6

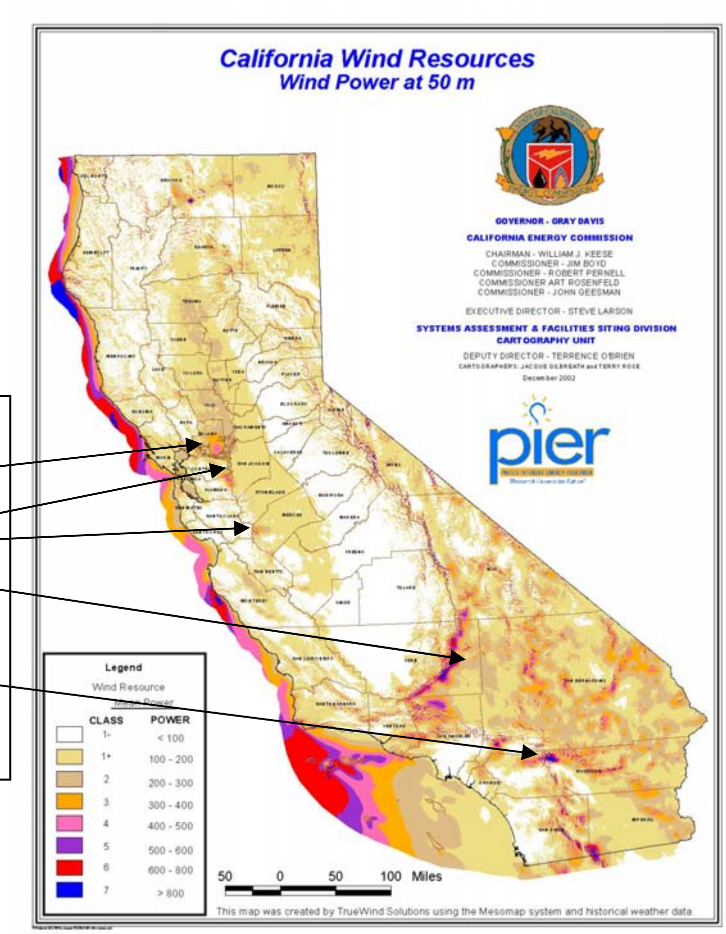

Figure 1-1 California Mean Wind Power Map at 50-m Elevation and 2005 Rated Capacity of Wind Generation at Principal Wind Resource Areas (California Energy Commission, 2006)

Wind generation is an intermittent resource and can not be dispatched or brought on-line on demand to meet an increase in load unless the wind blows at sufficient speed to generate the required power. Large concentrations of wind generation in one area can affect electricity grid operations, load following, and reserve requirements. System operators will need increasingly accurate wind forecast tools to manage wind and other intermittent generation resources connected to the California grid. Accurate next-hour and next-day forecasts will make it possible to optimize the response to rapid changes in wind generation to balance load and supply reserve and regulation resources.

Previous Energy Commission-EPRI Wind Energy Forecasting Project, 2001-2003

In 2002 the Energy Commission and EPRI completed testing two forecasting systems at Altamont and at San Gorgonio (Energy Commission and EPRI, 2003a and 2003b; EPRI, 2003). Two wind energy forecasting system developers, Risoe National Laboratory and TrueWind Solutions, applied their meteorology-based, meso-scale modeling algorithms to generate twice-daily, 48-hour forecasts of hourly wind speed and energy generation, during a 12-month period. The host wind projects were the 90 MW Wind Power Partners/Windworks project, operated by Powerworks at Altamont Pass, and the 66.6 MW Mountain View 1 and 2 wind project, operated by Seawest at San Gorgonio Pass. Based on the monthly and annual mean absolute errors (MAE) of the forecast vs. observed data, the Risoe and TrueWind forecasts performed better than simple persistence and climatology forecasts. However, the forecast errors were still significant, indicating that additional research is needed to incorporate improved forecast technology and forecast performance.

Current Regional Wind Energy Forecasting System Development Project, 2004-2005

In 2004, Energy Commission, EPRI, and California Independent System Operator (CA ISO) initiated a new 18-month project to build on the first project and develop and test improved wind energy forecast algorithms for both short-term forecasts (regional five-minute forecasts for a period of three hours) and intermediate-term forecasts (hourly wind plant forecasts for a period of 48 hours) in the principal wind resource areas of the state. The project was completed during 2005 and the results are presented in the four-volume report, *California Regional Wind Energy Forecasting System Development and Testing* (Energy Commission and EPRI, 2006a, 2006b, 2006c, and 2006d).

This report, *California Regional Wind Energy Forecasting System Development – Volume 4: California Wind Generation Research Dataset (CARD),* describes the basis of and how to access the CARD dataset. The other report volumes include *Volume 1: Executive Summary*; *Volume 2: Wind Energy Forecasting System Development and Testing and Numerical Modeling of Wind Flow over Complex Terrain*; and *Volume 3: Wind Tunnel Modeling of Wind Flow Over Complex Terrain* (Energy Commission and EPRI, 2006a, 2006b, and 2006c).

Objectives and Scope

The overall project objectives of the overall project include both economic and technical goals.

The economic goals include:

- Support the California Independent System Operator's (CA ISO) development of a viable competitive market for intermittent wind resources.

- Pave the way for increasing market penetration of renewable resources.

The technical goals include:

- Leverage the experiences gained under the prior forecasting efforts to improve forecast accuracy and

- Provide capabilities to generate accurate forecasts for both short-term and longer-term forecast timeframes.

The specific objectives include:

- Develop and test short-term forecasting algorithms with higher accuracy than persistence forecasts to provide real-time forecasting capability and support system real-time updates to meet dispatching needs;

- Determine sources of forecast error and assess methods to reduce errors for both next-hour and next-day forecasts, for example, improved input data, finer grid sizes in meso-scale models, and improved statistical models for short-term forecasting and model operating statistics.

- Investigate wind flow and wind plant power curve variations over complex terrain via wind tunnel and numerical modeling.

The project scope included:

- Generate real-time weather forecasts over a 4-km grid in both Northern and Southern California using the COAMPS meso-scale model.

- Develop and test wind energy forecast systems to provide forecasts for two "look-ahead" time horizons: (1) short-term forecasts of five-minute wind energy generation over a three-hour period to be issued every five minutes for the principal wind resource areas of the state (Solano, Altamont, Tehachapi, and San Gorgonio); and (2) intermediate-term forecasts of hourly wind generation over a 48-hour period issued twice daily or every 12 hours for wind plants in each of the principal wind resource areas.

- Conduct numerical and wind tunnel modeling of wind flow and power density at each wind turbine location vs. wind speed at a reference meteorological tower to investigate the variation of wind flow and wind plant power curve with wind speed and direction, atmospheric stability, and other conditions.

- Generate the California Wind Generation Research Dataset (CARD), a data base of daily forecasts of hourly wind generation at multiple elevations over 5-km grids in Northern and Southern California.

The project was conducted over the 18-month period, July 2004 through December 2005.

Project Participants

The project participants included the California Energy Commission as program manager, the Electric Power Research Institute (EPRI) as project manager, EPRI subcontractors AWS Truewind LLC, the University of California at Davis, and UC Davis subcontractor, Lawrence Livermore Laboratory; project advisors, California Independent System Operator, National Renewable Energy Laboratory, Southern California Edison, and five wind plant operators who together with CA ISO also provided wind resource and power data for their respective wind projects, Sacramento Municipal Power District, PPM/High Winds, PowerWorks, Oak Creek Energy Systems, and BMR/Mountain View 1 & 2.

The project consisted of six major tasks: Task 1: Project Review and Reporting; Task 2: Wind Resource Data Collection and Analysis; Task 3: Rapid-Update Wind Speed and Direction Forecast Algorithm; Task 4: Regional Short-Term Wind Energy Forecasting System Development and Testing; Task 5: Long-Term Wind Energy Forecasting System Development and Testing; and Task 6: Wind Tunnel Testing Coupled with Advanced Numerical Model Data.

CARD Dataset Overview

The need for a detailed four-dimensional (or space and time) database of atmospheric parameters relevant to the wind energy industry was identified by the Energy Commission and other participants in California's wind energy industry. The database addresses the need to supply input data to various types of engineering, economic, and policy models used in planning for the development of California's wind resource.

The concept of the California Wind Generation Dataset (CARD) was formulated in response to this need. The original vision was that the CARD database would consist of a wide variety of measurement data from both proprietary and public sources. It was envisioned that the database would consist of data from both in situ and remote-sensing measurement devices. However, a number of issues arose with this version of the concept.

First, much of the in situ data relevant to the wind industry are proprietary, and access to the data typically comes with a variety of restrictions on the permitted uses and users. Such data would be difficult to include in a database while adhering to these restrictions.

Second, the data from different measurement systems often exhibit substantially different accuracy, scales of representativeness, and spatial and temporal coverage characteristics. Thus, these different systems make it difficult to construct a composite representation of the behavior of the wind for a specific region (for example, the area of a wind plant) from different sensors. The user would commonly ignore unfamiliar data types and rely on those that have characteristics that are familiar to the user.

Third, the spatial and temporal coverage provided by measurement data is typically characterized by large gaps for which no data are available due to the limitations of the measuring devices.

An approach that addresses many of these issues is to create a database of numerically-simulated data from a physics-based atmospheric model. Physics-based atmospheric models ingest data from a wide variety of atmospheric sensors and create a physically consistent three-dimensional dataset of all of the basic atmospheric variables.

The CARD database uses the numerical simulation approach. The objectives were to design, create and document the CARD database. The structure of the database takes advantage of the physics-based numerical simulations that were generated to produce one year of forecasts, described in Volume 2 (Energy Commission and EPRI, 2006b).

This report describes the method used to create the CARD database, documents the structure and contents of the database, provides examples of some of the fields in the database, and documents two programs provided to extract data from the database. The details of the numerical simulations used to populate the CARD database are specified in Section 2. Section 3 documents the structure and contents of the database. Section 4 provides examples of a few of the summary statistics. The documentation of the data extraction programs is presented in Section 5.

Report Organization

This report describes the method used to create the CARD database, documents the structure and contents of the database, provides examples of some of the fields in the database, and documents two programs provided to extract data from the database.

The report consists of seven chapters, including Chapter 1, Introduction.

Chapter 2, CARD Dataset Creation, describes the numerical simulations that generated the CARD database.

Chapter 3, CARD Dataset Structure and Contents, documents the structure and contents of the CARD database.

Chapter 4, CARD Dataset Examples, provides examples of a few of the summary statistics.

Chapter 5, Data Extraction Programs, provides documentation for the data extraction programs

Chapter 6, Summary, describes the CARD dataset of wind energy forecasts at multiple elevations over 5-km grids in Northern and Southern California and generated using NOAA-NCEP forecast data and AWS Truewind's MASS 6 model for the period July 1, 2004 through June 30, 2005.

Chapter 7 presents the references.

2
CARD DATASET CREATION

This chapter describes how the CARD dataset was generated and the contents of the CARD dataset.

Methodology

The CARD dataset uses data from the numerical atmospheric simulations executed during the generation of the one year of 48-hour forecasts of hourly wind power production, described in Volume 2 (Energy Commission and EPRI 2006b). The forecasts were generated during the July 1, 2004, to June 20, 2005, period at five wind plants in California

The algorithms used to generate the forecasts used high-resolution physics-based simulations of the atmosphere over the regional area surrounding each wind plant.

The outputs from these simulations were also used to create the CARD database.

Mesoscale Atmospheric Simulation System Version 6 (MASS-6)

The atmospheric model used to generate the simulations was Version 6 of the Mesoscale Atmospheric Simulation System (MASS) model. The MASS model stemmed from the 1980s as part of NASA's research activities in the development of new remote sensing systems (Kaplan et al, 1982). The model evolved over the ensuing 20 years by incorporating new representations of various physical processes as they became available. Version 5 of the MASS model was used to generate the forecast simulations for the previous Energy Commission-EPRI forecast evaluation project (Energy Commission and EPRI, 2003a and 2003b).

Nested Grids

The MASS 6 forecast simulations were generated on a nested grid system consisting of three grids. An outer grid of 100 by 80 grid cells with a cell size of 20 km was used to simulate the larger scale flow over the southwestern United States, the adjacent Pacific Ocean, and Mexico. This is referred to as the "A" grid. Figure 2-1 shows the geographical domain covered by the A grid.

Two higher-resolution grids were nested inside of the A grid and designated the "B" and "C" grids. Both of the high-resolution grids employed an 80 by 80 matrix of grid cells and a grid cell size of 5 km. The B grid was centered over the Bay Area of Northern California, shown in

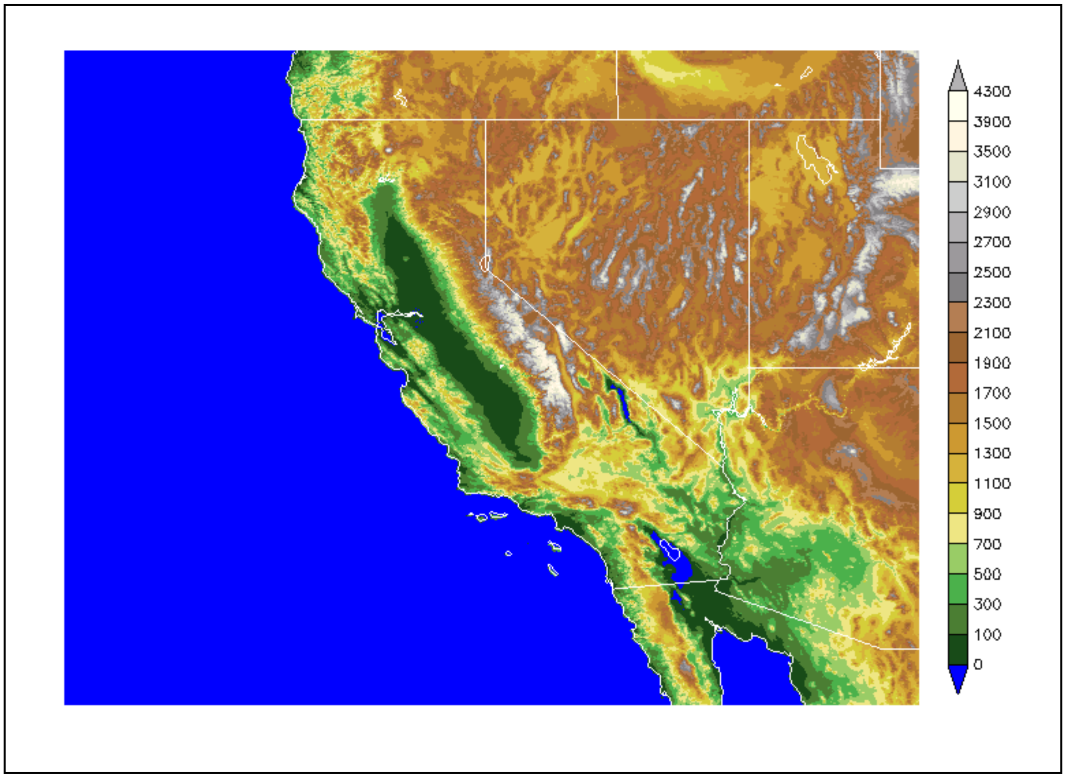

Figure 2-1 The geographical domain covered by the 100 X 80 matrix of 20-km grid cells used to produce the parent coarse grid MASS 6 simulations for the project (A Grid)

Figure 2-2, and generated forecast data for the PowerWorks, SMUD and High Winds wind plants. The C grid centered over Southern California, shown in Figure 2-3, and was used to generate forecast data for the Oak Creek and Mountain View wind plants.

Initialization of Simulations

The physics-based simulations were initialized twice per day. The initialization times were 0000 UTC (4:00 PM PST) and 1200 UTC (4:00 AM PST), where UTC refers to the Coordinated Universal Time. The data required to specify the initial conditions and the lateral boundary conditions came from initialization analysis and forecast grid point data from NCEP's Global Forecast System (GFS). The atmospheric model used in the GFS is a spectral model and not a grid point model.

The CARD data were extracted from hours 9 through 32 of the numerical simulations initialized at 0000 UTC of each day. Since 0000 UTC corresponds to 4:00 PM PST, hour 9 of the simulation corresponds the hour ending at 1:00 AM on the day after the initialization of the simulation, and hour 32 corresponds to the hour ending at the following midnight. Thus the database consists of a concatenation of the 24 hours of physics-based model output representing the period from hour 9 (1:00 AM) to hour 32 (midnight) of each day's numerical simulation.

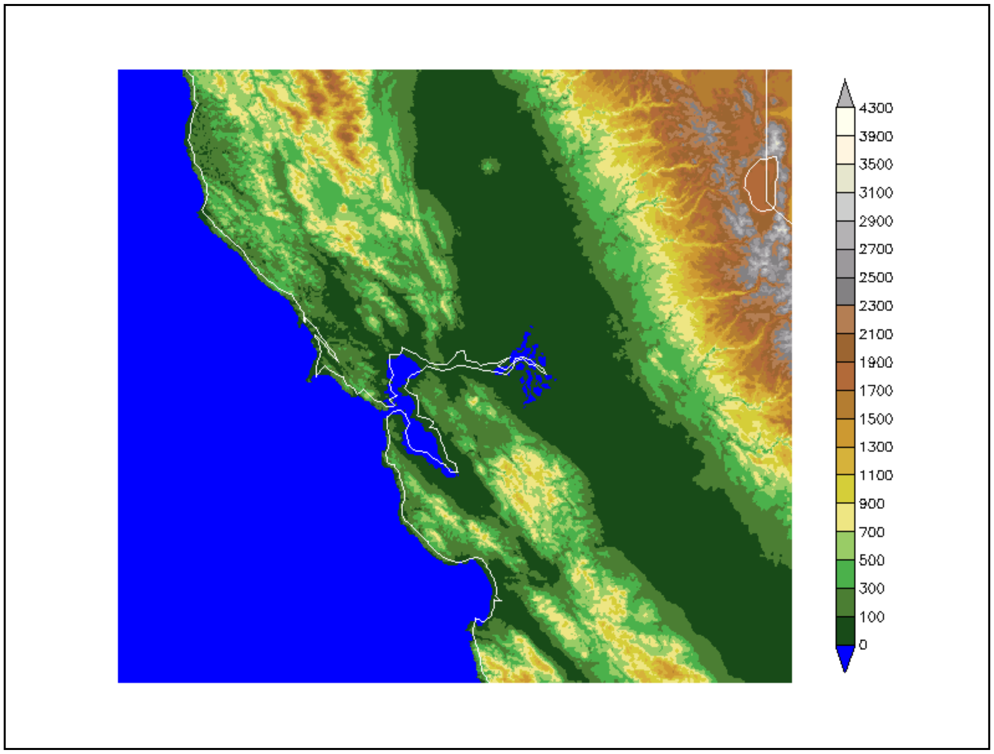

Figure 2-2 The Northern California geographical domain covered by the 80 X 80 matrix of 5-km grid cells used to produce the high-resolution MASS 6 simulations (B Grid)

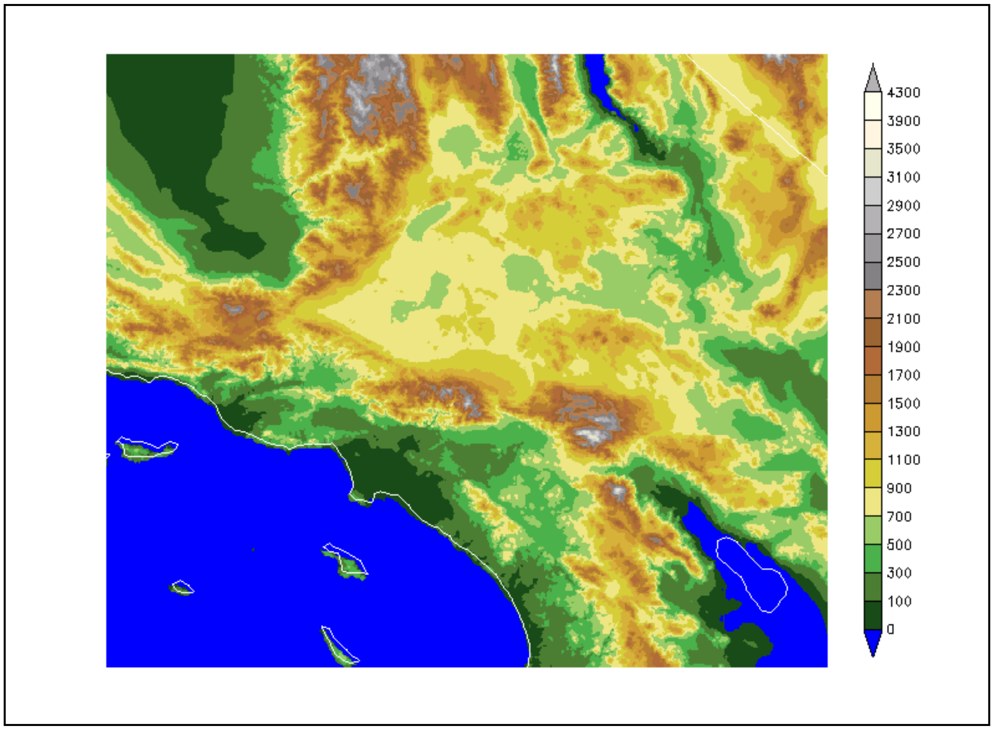

Figure 2-3 The Southern California geographical domain covered by the 80 X 80 matrix of 5-km grid cells used to produce the high-resolution MASS 6 (C Grid)

CARD Dataset Contents

The CARD dataset consists of two-dimensional fields of selected variables (grid point values) at one-hour intervals and at each grid point of the 5-km forecast grids over Northern and Southern California (Figures 2-2 and 2-3).

The database variables are wind direction (degrees), wind speed m/s), air density(kg/m^2), temperature (C), water vapor mixing ratio (kg/kg) at 10, 30, 50, 70, 100, 300, 600 and 1000 meters above ground level, and the wind power density at 10, 30, 50, and 70 meters above ground level.

3
CARD DATASET STRUCTURE AND CONTENTS

This chapter provides an overview of the directory structure and the contents of the data files included in the CARD database.

Directory Structure

Figure 3-1 illustrates the directory structure of the CARD database. The top level of the directory structure is designated CALR1. All of the raw data files in the CARD database are found under the CALR1 directory. There are two subdirectories within the CALR1 directory, one for the Northern California B grid and one for the Southern California C grid.

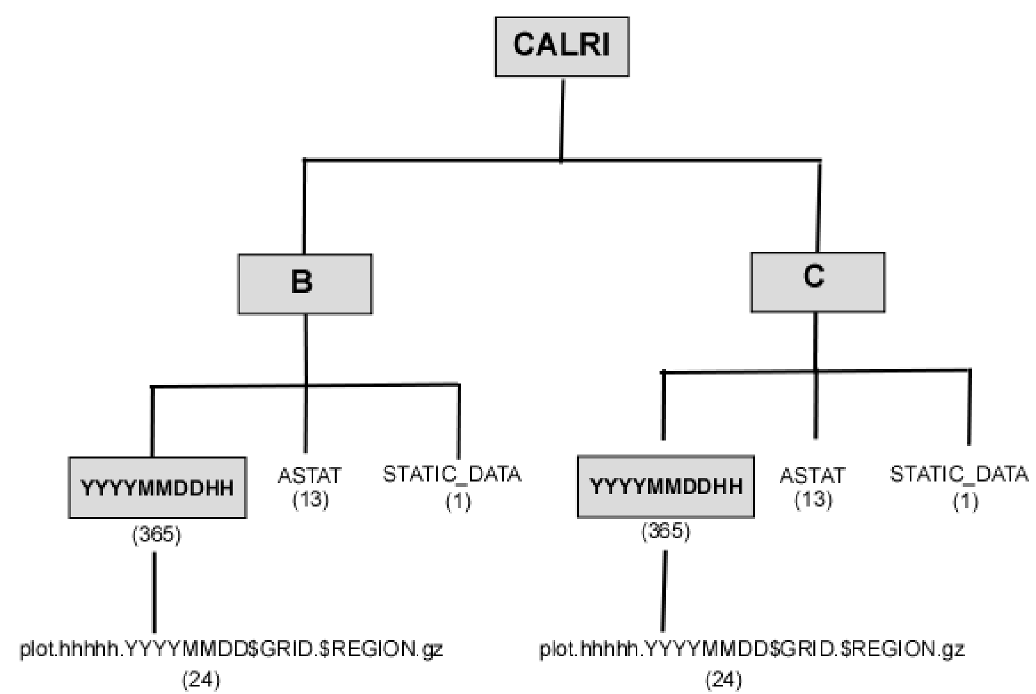

Figure 3-1 Directory structure of the CARD database; the shaded boxes denote directories. Names not enclosed in boxes are files. The numbers in parentheses indicate the number of files or directories in each database element. See text for explanation of directory and file names.

Each of the individual grid directories (B and C) contains 365 dated directories, an ASTAT directory, and a STATIC_DATA file.

Dated Directories and Hourly Grid Point Data Files

There is one dated directory for each day of the one-year period from July 1, 2004, to June 30, 2005 (B and C grids). Each dated directory contains 24 individual data files, and each file contains grid point values of all database variables for one hour of the PST calendar day denoted by the directory name.

The naming convention of the dated directories is YYYYMMDDHH, where YYYY is the 4-digit year, MM is the two-digit month, DD is the two-digit day, and HH is the two-digit UTC time of initialization of the model simulation that generated the data. For example, the directory name of the model simulation initialized at 0000 UTC on July 1, 2004 is 2004070100.

ASTAT Directory and Summary Statistic Files

One ASTAT directory contains 13 summary statistics files for each month of the year and for the year as a whole within each grid directory (B and C).

Each summary statistics file provides monthly or annual statistical data, including the monthly or annual mean, maximum, minimum, and standard deviation of each database variable, as well as the prevailing (most frequently occurring) wind direction at each elevation in the database.

The file name convention for the annual ASTAT summary statistics is ASTATALL$GRID. $REGION, where $GRID is the grid designator (B or C) and $REGION is the region name.

The file name convention for the 12 monthly ASTAT summary statistics is ASTATYYYYMM$GRID. $REGION, where YYYY is the four digit year, MM is the two digit month (01= January, 12=December), $GRID is the grid identifier (B or C), and $REGION is the region name.

STATIC_DATA Directory and Terrain and Elevation Data Files

There is one STATIC_DATA file within each grid directory (B and C), which contains two-dimensional arrays of terrain elevation, latitude, and longitude for each grid point.

ASTAT Summary Statistics Files

The ASTAT summary statistics files provide monthly and annual statistical data for the database variables (mean, maximum, minimum, standard deviation, and prevailing wind direction).

Tables 3-1 and 3-2 specify the contents of the ASTAT.

Table 3-2 provides details on the header information at the beginning of each file and Table 3-3 specifies the complete list of fields contained in each file. The data for each variable are output beginning in the southwest corner of the grid at point (1,1). Each row of data contains up to 11 values that increase in the X direction. So the first row of variable data contains data for the following grid points: (1,1), (2,1), (3,1), (4,1), (5,1), (6,1), (7,1), (8,1), (9,1), (10,1), (11,1). Eleven values are output to each line as long as I, J points remain. The data are output from the southwest corner to the northeast corner for each variable.

Table 3-1 ASTAT File Contents

Line	Description
1	Meaningless
2	Meaningless
3	ISW,INE,JSW,JNE,DELX,IPROJ,CLAT,CLON,ANYLAT,ANYLON,ANYX,ANYY ISW - I grid point of southwest corner of model grid. INE - I grid point of northeast corner of model grid. JSW - J grid point of southwest corner of model grid. JNE - J grid point of northeast corner of model grid. DELX - Model grid point spacing. IPROJ - Geographic projection used for model data 1 - Polar Stereographic 2 - Mercator 3 - Lambert Conformal CLAT - latitude at which the projection is true (i.e. where the grid spacing is exactly equal to DELX. CLON - longitude at which the projection is centered. ANYLAT - latitude of the calibration grid point (ANYX,ANYY) ANYLON - longitude of the calibration grid point (ANYX,ANYY) ANYX,ANYY - grid point corresponding to the calibration latitude, longitude (ANYLAT,ANYLON)
4 to End of File	Headers and data for the 152 summary variables listed in Table 3-2

Table 3-2 Fields in the ASTAT files

FIELD #	FIELD DESCRIPTION	UNITS	STATISTIC	LEVEL
1	Wind Direction	degrees	PREVAILING	10 m
2	Wind Direction	degrees	PREVAILING	30 m
3	Wind Direction	degrees	PREVAILING	50 m
4	Wind Direction	degrees	PREVAILING	70 m
5	Wind Direction	degrees	PREVAILING	100 m
6	Wind Direction	degrees	PREVAILING	300 m
7	Wind Direction	degrees	PREVAILING	600 m
8	Wind Direction	degrees	PREVAILING	1000 m
9	Wind Speed	m/s	MEAN	10 m
10	Wind Speed	m/s	MEAN	30 m
11	Wind Speed	m/s	MEAN	50 m
12	Wind Speed	m/s	MEAN	70 m
13	Wind Speed	m/s	MEAN	100 m
14	Wind Speed	m/s	MEAN	300 m
15	Wind Speed	m/s	MEAN	600 m
16	Wind Speed	m/s	MEAN	1000 m
17	Wind Speed	m/s	STDEV	10 m
18	Wind Speed	m/s	STDEV	30 m
19	Wind Speed	m/s	STDEV	50 m
20	Wind Speed	m/s	STDEV	70 m
21	Wind Speed	m/s	STDEV	100 m
22	Wind Speed	m/s	STDEV	300 m
23	Wind Speed	m/s	STDEV	600 m
24	Wind Speed	m/s	STDEV	1000 m
25	Wind Speed	m/s	MAX	10 m
26	Wind Speed	m/s	MAX	30 m
27	Wind Speed	m/s	MAX	50 m
28	Wind Speed	m/s	MAX	70 m
29	Wind Speed	m/s	MAX	100 m
30	Wind Speed	m/s	MAX	300 m
31	Wind Speed	m/s	MAX	600 m
32	Wind Speed	m/s	MAX	1000 m
33	Wind Speed	m/s	MIN	10 m
34	Wind Speed	m/s	MIN	30 m
35	Wind Speed	m/s	MIN	50 m
36	Wind Speed	m/s	MIN	70 m
37	Wind Speed	m/s	MIN	100 m
38	Wind Speed	m/s	MIN	300 m
39	Wind Speed	m/s	MIN	600 m
40	Wind Speed	m/s	MIN	1000 m

FIELD #	FIELD DESCRIPTION	UNITS	STATISTIC	LEVEL
41	Air Density	kg/m**3	MEAN	10 m
42	Air Density	kg/m**3	MEAN	30 m
43	Air Density	kg/m**3	MEAN	50 m
44	Air Density	kg/m**3	MEAN	70 m
45	Air Density	kg/m**3	MEAN	100 m
46	Air Density	kg/m**3	MEAN	300 m
47	Air Density	kg/m**3	MEAN	600 m
48	Air Density	kg/m**3	MEAN	1000 m
49	Air Density	kg/m**3	STDEV	10 m
50	Air Density	kg/m**3	STDEV	30 m
51	Air Density	kg/m**3	STDEV	50 m
52	Air Density	kg/m**3	STDEV	70 m
53	Air Density	kg/m**3	STDEV	100 m
54	Air Density	kg/m**3	STDEV	300 m
55	Air Density	kg/m**3	STDEV	600 m
56	Air Density	kg/m**3	STDEV	1000 m
57	Air Density	kg/m**3	MAX	10 m
58	Air Density	kg/m**3	MAX	30 m
59	Air Density	kg/m**3	MAX	50 m
60	Air Density	kg/m**3	MAX	70 m
61	Air Density	kg/m**3	MAX	100 m
62	Air Density	kg/m**3	MAX	300 m
63	Air Density	kg/m**3	MAX	600 m
64	Air Density	kg/m**3	MAX	1000 m
65	Air Density	kg/m**3	MIN	10 m
66	Air Density	kg/m**3	MIN	30 m
67	Air Density	kg/m**3	MIN	50 m
68	Air Density	kg/m**3	MIN	70 m
69	Air Density	kg/m**3	MIN	100 m
70	Air Density	kg/m**3	MIN	300 m
71	Air Density	kg/m**3	MIN	600 m
72	Air Density	kg/m**3	MIN	1000 m
73	Temperature	C	MEAN	10 m
74	Temperature	C	MEAN	30 m
75	Temperature	C	MEAN	50 m
76	Temperature	C	MEAN	70 m
77	Temperature	C	MEAN	100 m
78	Temperature	C	MEAN	300 m
79	Temperature	C	MEAN	600 m
80	Temperature	C	MEAN	1000 m
81	Temperature	C	STDEV	10 m
82	Temperature	C	STDEV	30 m
83	Temperature	C	STDEV	50 m

FIELD #	FIELD DESCRIPTION	UNITS	STATISTIC	LEVEL
84	Temperature	C	STDEV	70 m
85	Temperature	C	STDEV	100 m
86	Temperature	C	STDEV	300 m
87	Temperature	C	STDEV	600 m
88	Temperature	C	STDEV	1000 m
89	Temperature	C	MAX	10 m
90	Temperature	C	MAX	30 m
91	Temperature	C	MAX	50 m
92	Temperature	C	MAX	70 m
93	Temperature	C	MAX	100 m
94	Temperature	C	MAX	300 m
95	Temperature	C	MAX	600 m
96	Temperature	C	MAX	1000 m
97	Temperature	C	MIN	10 m
98	Temperature	C	MIN	30 m
99	Temperature	C	MIN	50 m
100	Temperature	C	MIN	70 m
101	Temperature	C	MIN	100 m
102	Temperature	C	MIN	300 m
103	Temperature	C	MIN	600 m
104	Temperature	C	MIN	1000 m
105	H2O Vapor Mixing Ratio	kg/kg	MEAN	10 m
106	H2O Vapor Mixing Ratio	kg/kg	MEAN	30 m
107	H2O Vapor Mixing Ratio	kg/kg	MEAN	50 m
108	H2O Vapor Mixing Ratio	kg/kg	MEAN	70 m
109	H2O Vapor Mixing Ratio	kg/kg	MEAN	100 m
110	H2O Vapor Mixing Ratio	kg/kg	MEAN	300 m
111	H2O Vapor Mixing Ratio	kg/kg	MEAN	600 m
112	H2O Vapor Mixing Ratio	kg/kg	MEAN	1000 m
113	H2O Vapor Mixing Ratio	kg/kg	STDEV	10 m
114	H2O Vapor Mixing Ratio	kg/kg	STDEV	30 m
115	H2O Vapor Mixing Ratio	kg/kg	STDEV	50 m
116	H2O Vapor Mixing Ratio	kg/kg	STDEV	70 m
117	H2O Vapor Mixing Ratio	kg/kg	STDEV	100 m
118	H2O Vapor Mixing Ratio	kg/kg	STDEV	300 m
119	H2O Vapor Mixing Ratio	kg/kg	STDEV	600 m
120	H2O Vapor Mixing Ratio	kg/kg	STDEV	1000 m
121	H2O Vapor Mixing Ratio	kg/kg	MAX	10 m
122	H2O Vapor Mixing Ratio	kg/kg	MAX	30 m
123	H2O Vapor Mixing Ratio	kg/kg	MAX	50 m
124	H2O Vapor Mixing Ratio	kg/kg	MAX	70 m
125	H2O Vapor Mixing Ratio	kg/kg	MAX	100 m
126	H2O Vapor Mixing Ratio	kg/kg	MAX	300 m

FIELD #	FIELD DESCRIPTION	UNITS	STATISTIC	LEVEL
127	H2O Vapor Mixing Ratio	kg/kg	MAX	600 m
128	H2O Vapor Mixing Ratio	kg/kg	MAX	1000 m
129	H2O Vapor Mixing Ratio	kg/kg	MIN	10 m
130	H2O Vapor Mixing Ratio	kg/kg	MIN	30 m
131	H2O Vapor Mixing Ratio	kg/kg	MIN	50 m
132	H2O Vapor Mixing Ratio	kg/kg	MIN	70 m
133	H2O Vapor Mixing Ratio	kg/kg	MIN	100 m
134	H2O Vapor Mixing Ratio	kg/kg	MIN	300 m
135	H2O Vapor Mixing Ratio	kg/kg	MIN	600 m
136	H2O Vapor Mixing Ratio	kg/kg	MIN	1000 m
137	Wind Power Density	W/m**2	MEAN	30 m
138	Wind Power Density	W/m**2	MEAN	50 m
139	Wind Power Density	W/m**2	MEAN	70 m
140	Wind Power Density	W/m**2	MEAN	100 m
141	Wind Power Density	W/m**2	STDEV	30 m
142	Wind Power Density	W/m**2	STDEV	50 m
143	Wind Power Density	W/m**2	STDEV	70 m
144	Wind Power Density	W/m**2	STDEV	100 m
145	Wind Power Density	W/m**2	MAX	30 m
146	Wind Power Density	W/m**2	MAX	50 m
147	Wind Power Density	W/m**2	MAX	70 m
148	Wind Power Density	W/m**2	MAX	100 m
149	Wind Power Density	W/m**2	MIN	30 m
150	Wind Power Density	W/m**2	MIN	50 m
151	Wind Power Density	W/m**2	MIN	70 m
152	Wind Power Density	W/m**2	MIN	100 m

PLOT* Hourly Data Files

Each dated directory contains a total of 24 individual data files. The raw data files in each dated directory provide data for each of the 24 hours of the day specified in the directory name. A day of data is defined by the 24 hourly data files starting at 1:00 AM and extending to midnight Pacific Standard Time (PST) of the same calendar day.

The raw data files range from plot.00009 through plot.00032, representing hours 9 through 32.

Since the model runs were initialized at 0000 UTC (4:00 PM PST) on the day specified in the filename, a plot.00009 file represents model hour 9, which is 0900 UTC or 1:00 am PST of the current day. Similarly the plot.00032 file represents model hour 32, which is 0800 UTC of next day or 12:00 AM PST of the date specified in the directory name. Therefore each dated directory contains 24 hours of data covering the period, 1:00 AM PST to 12:00 AM PST.

Each plot file is compressed using the *gzip* protocol to save space. The **extract_timeseries** program that reads the plot files is able to read the gzipped files directly.

Tables 3-3 and 3-4 specify the contents of each plot file. The data for each variable are output beginning in the southwest corner of the grid at point (1,1) in the same manner described above for the summary statistics (ASTAT) files.

Table 3-3 PLOT file contents.

Line	Description
1	DD YYYY HHHH - Initialization time (UTC) of model used to create plot file
2	DD YYYY HHHH - Time (UTC) data is valid for
3	ISW,INE,JSW,JNE,DELX,IPROJ,CLAT,CLON,ANYLAT,ANYLON,ANYX,ANYY,CLAT2 ISW - I grid point of southwest corner of model grid. INE - I grid point of northeast corner of model grid. JSW - J grid point of southwest corner of model grid. JNE - J grid point of northeast corner of model grid. DELX - Model grid point spacing. IPROJ - Geographic projection used for model data 1 - Polar Stereographic 2 - Mercator 3 - Lambert Conformal CLAT - latitude at which the projection is true (i.e. where the grid spacing is exactly equal to DELX. CLON - longitude at which the projection is centered. ANYLAT - latitude of the calibration grid point (ANYX,ANYY) ANYLON - longitude of the calibration grid point (ANYX,ANYY) ANYX,ANYY - grid point corresponding to the calibration latitude, longitude (ANYLAT,ANYLON) CLAT2 - second latitude at which the projection is true. Only used for lambert conformal grids.
4 to End of File	Headers and data for the 44 variables listed in Table 3-4

Table 3-4 Fields in the hourly plot files

Field #	FIELD DESCRIPTION	UNITS	LEVEL
1	Earth Relative Wind Speed	m/s	10 m
2	Earth Relative Wind Speed	m/s	30 m
3	Earth Relative Wind Speed	m/s	50 m
4	Earth Relative Wind Speed	m/s	70 m
5	Earth Relative Wind Speed	m/s	100 m
6	Earth Relative Wind Speed	m/s	300 m
7	Earth Relative Wind Speed	m/s	600 m
8	Earth Relative Wind Speed	m/s	1000 m
9	Earth Relative Wind Direction	degrees	10 m
10	Earth Relative Wind Direction	degrees	30 m
11	Earth Relative Wind Direction	degrees	50 m
12	Earth Relative Wind Direction	degrees	70 m
13	Earth Relative Wind Direction	degrees	100 m
14	Earth Relative Wind Direction	degrees	300 m
15	Earth Relative Wind Direction	degrees	600 m
16	Earth Relative Wind Direction	degrees	1000 m
17	Air Density	kg/m**3	10 m
18	Air Density	kg/m**3	30 m
19	Air Density	kg/m**3	50 m
20	Air Density	kg/m**3	70 m
21	Air Density	kg/m**3	100 m
22	Air Density	kg/m**3	300 m
23	Air Density	kg/m**3	600 m
24	Air Density	kg/m**3	1000 m
25	Temperature	degrees C	10 m
26	Temperature	degrees C	30 m
27	Temperature	degrees C	50 m
28	Temperature	degrees C	70 m
29	Temperature	degrees C	100 m
30	Temperature	degrees C	300 m
31	Temperature	degrees C	600 m
32	Temperature	degrees C	1000 m
33	H2O Vapor Mixing Ratio	kg/kg	10 m
34	H2O Vapor Mixing Ratio	kg/kg	30 m
35	H2O Vapor Mixing Ratio	kg/kg	50 m
36	H2O Vapor Mixing Ratio	kg/kg	70 m
37	H2O Vapor Mixing Ratio	kg/kg	100 m
38	H2O Vapor Mixing Ratio	kg/kg	300 m
39	H2O Vapor Mixing Ratio	kg/kg	600 m
40	H2O Vapor Mixing Ratio	kg/kg	1000 m
41	Wind Power Density	W/m**2	10 m
42	Wind Power Density	W/m**2	30 m
43	Wind Power Density	W/m**2	50 m
44	Wind Power Density	W/m**2	70 m

4
CARD DATASET EXAMPLES

As noted previously, the CARD database consists of two types of data files: hourly data and summary data. The hourly data files contain the values of the individual parameters for each grid point for each hour of the one-year period. The summary data files contain summary statistics such as the maximum, minimum, mean, and standard deviation for each of the variables included in the CARD dataset. Table 3-3 in the previous section lists the summary statistics included in the database. Of course, the database user can calculate other summary statistics directly from the hourly data files.

Figures 4-1 through 4-10 show examples of the summary statistics included in the CARD database.

Mean Wind Speed

Figures 4-1 and 4-2 depict the mean wind speed at 50 m above ground level (AGL) for the Northern and Southern California grids.

These charts are not wind resource maps but simply a composite of the hourly wind speeds from one specific year (July 2004 through June 2005) of numerical simulations. This period may have experienced some anomalous wind regimes, and thus the average wind speed for this period may not be representative of the long-term average.

Also, the charts present raw physics-based model output data, which can contain biases resulting from small-scale circulations that are too small for the numerical model grid to resolve.

Therefore, the actual measured average wind speeds may be somewhat different from the values obtained using the simulated wind speeds extracted from the database at a specific location and time covered by the CARD database.

Mean Wind Power Density

Figures 4-3 and 4-4 depict the mean wind power density at 50 m AGL for the July 2004 through June 2005 period. The actual long-term average at a site may differ significantly from the one-year average.

The Solano and Altamont wind resource regions are evident in Figures 4-1 and 4-3 and the Tehachapi and San Gorgonio wind resource areas, in Figures 4-2 and 4-4. The regions of maximum wind speed and maximum power density are generally well aligned. Some regions of high mountains, such as in the Sierra to the east of San Francisco, have relatively high wind speeds during the period but, due to the low air density at the high elevation, these areas do not have very high power densities.

Maximum Hourly Average Wind Speed

Figures 4-5 and 4-6 depict the maximum hourly-average wind speed at 50 m AGL. The regions with the highest maximum hourly wind speeds were not aligned with the important wind resource regions.

The highest wind speeds tended to occur in the mountains rather than the passes where most of the wind generation is located.

Maximum and Minimum Hourly Average Air Density

Figures 4-7 and 4-8 show the maximum hourly average air density for the Northern and Southern California grids during the July 2004 through June 2005 period. Figures 4-9 and 4-10 show the minimum hourly average air density.

Comparison of Figures 4-7 through 4-10 with Figures 2-2 and 2-3 indicates that the regions of high (low) maximum air density are, as expected, located in regions of low (high) elevation rather than in regions with colder temperatures near sea level.

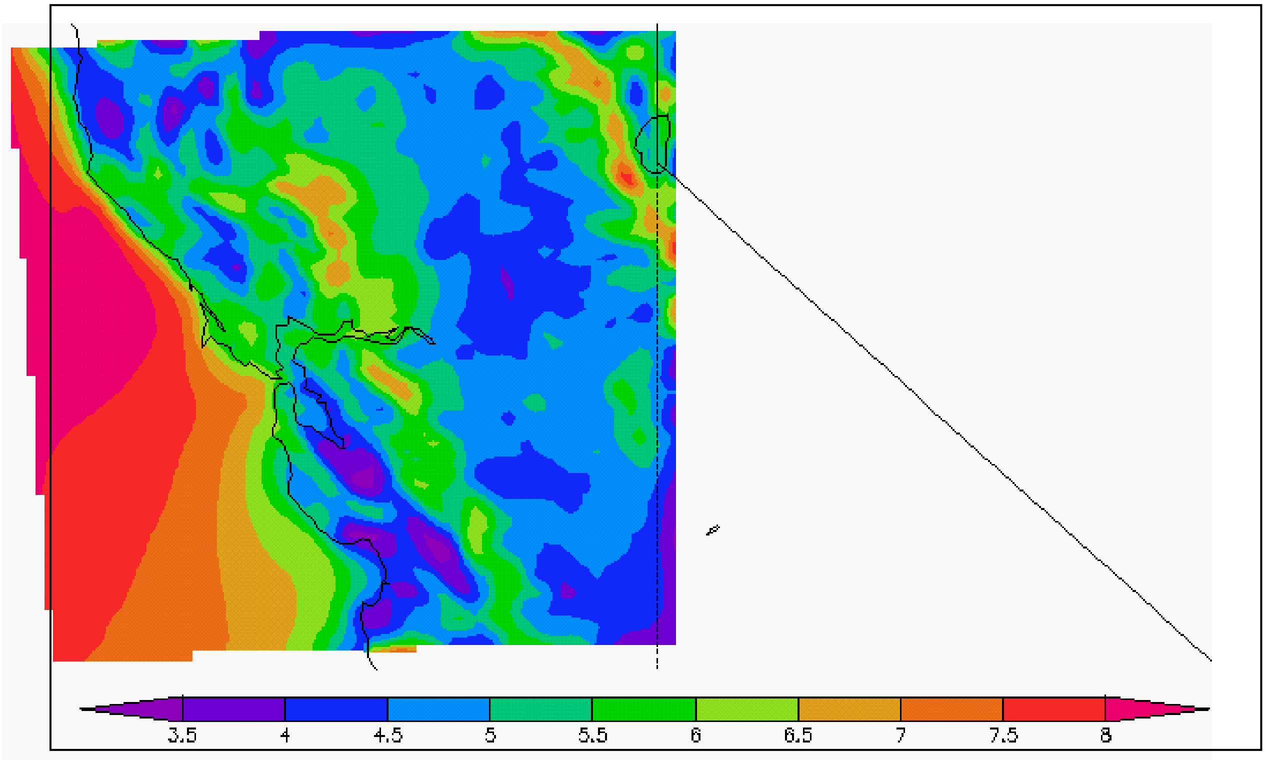

Figure 4-1 The simulated mean 50-m AGL wind speed for the Northern California 5-km grid (Grid B) for the period July 2004 to June 2005, physics-based numerical forecast simulations using the MASS-6 atmospheric model.

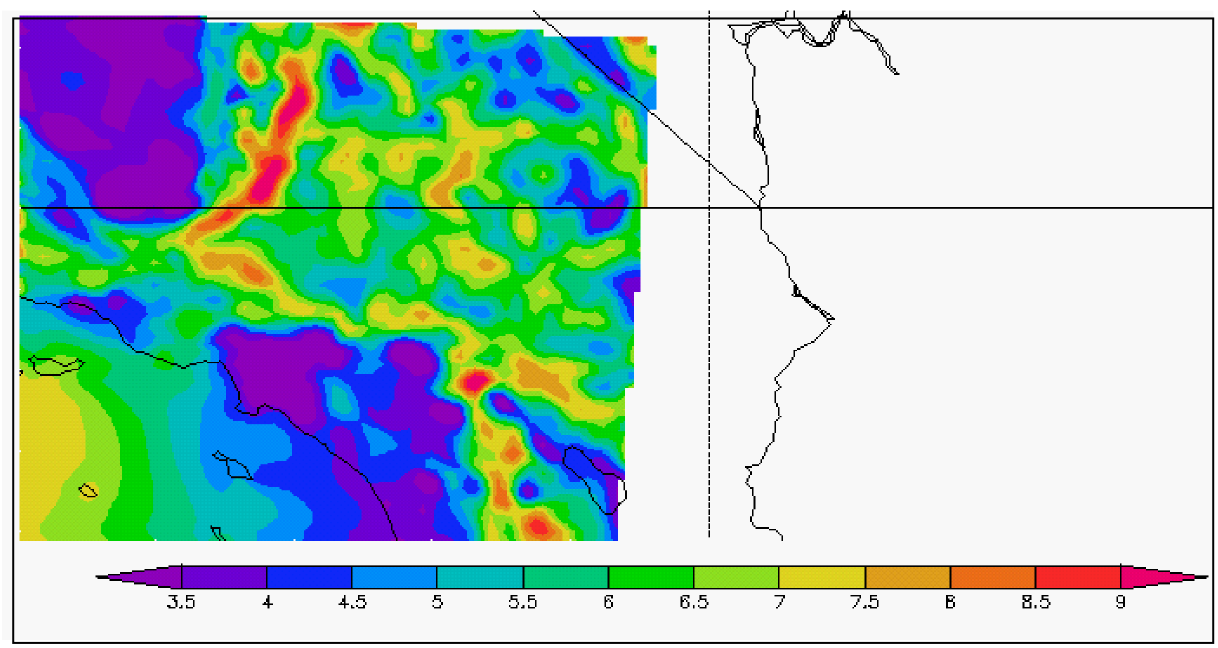

Figure 4-2 The simulated mean 50-m AGL wind speed for the Southern California 5-km grid (Grid C) for the period July 2004 to June 2005, physics-based numerical forecast simulations using the MASS-6 atmospheric model.

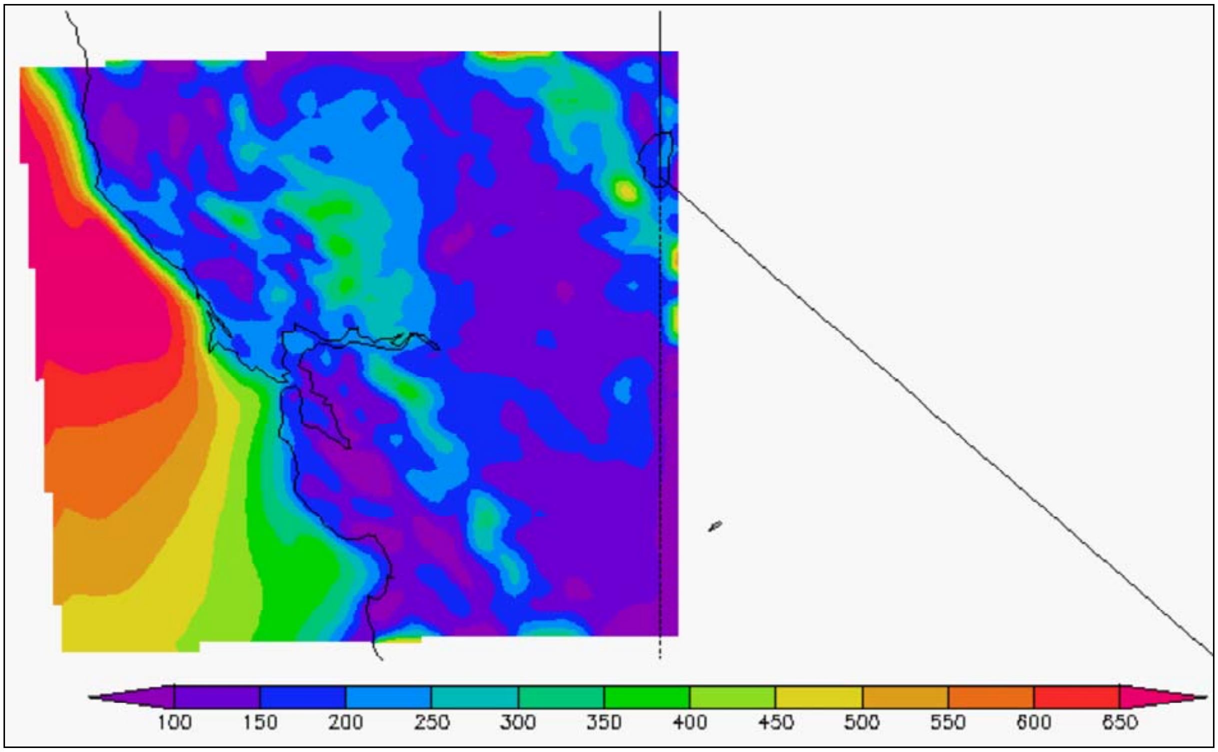

Figure 4-3 The simulated mean 50-m AGL wind power density (watts/m2) for the Northern California grid (Grid B) for the one-year period July 2004 to June 2005, daily physics-based numerical forecast simulations using the MASS-6 atmospheric model.

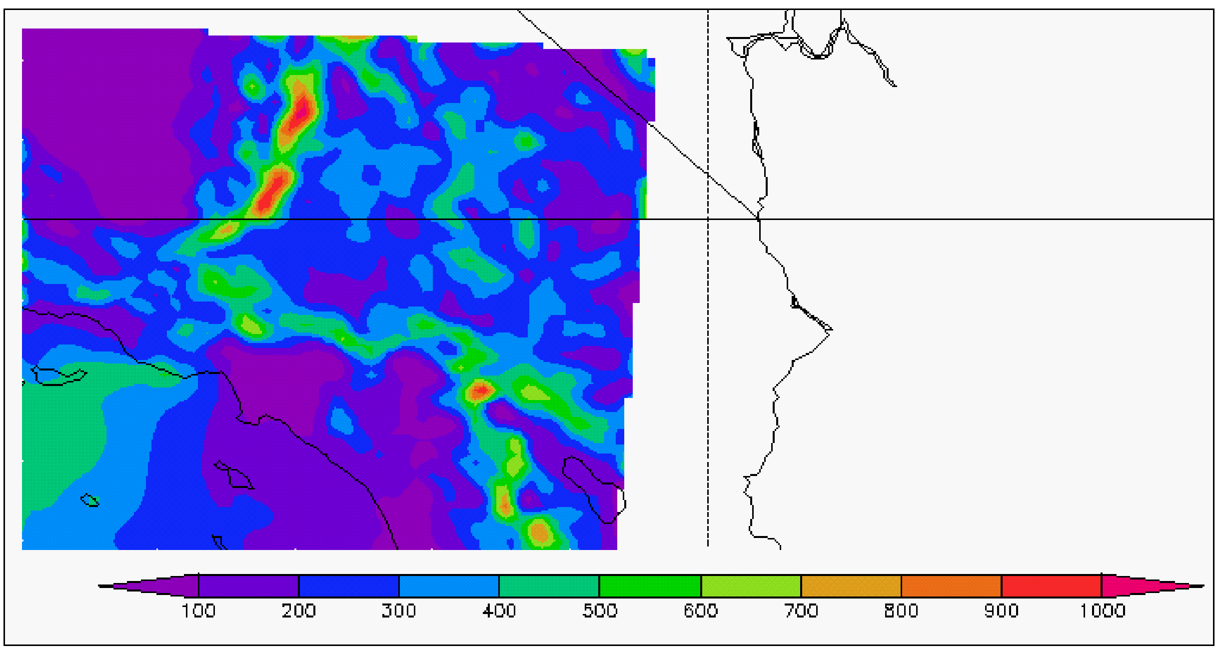

Figure 4-4 The simulated mean 50-m AGL wind power density (watts/m2) for the Southern California 5-km grid (Grid C) for the one-year period July 2004 to June 2005, daily physics-based numerical forecast simulations using the MASS-6 atmospheric model.

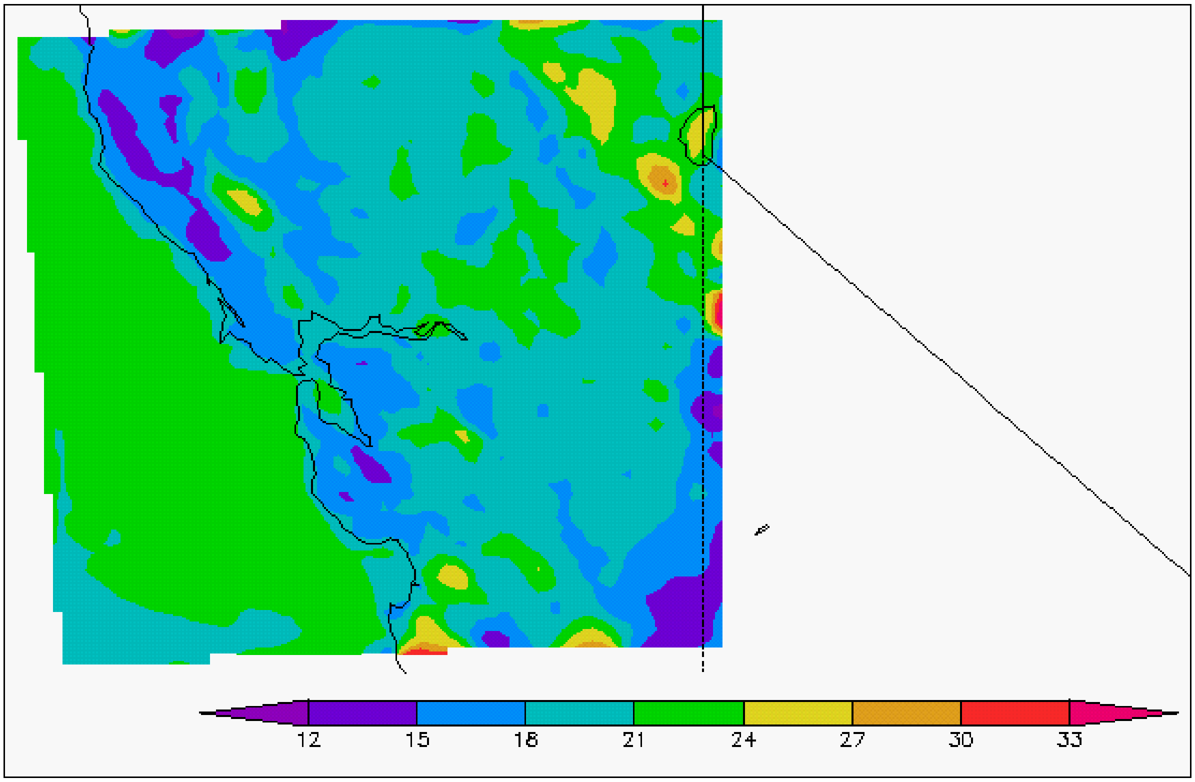

Figure 4-5 The simulated maximum 50-m AGL hourly-average wind speed (m/s) for the Northern California 5-km grid (Grid B) and the period July 2004 to June 2005, physics-based numerical forecast simulations using the MASS-6 atmospheric model.

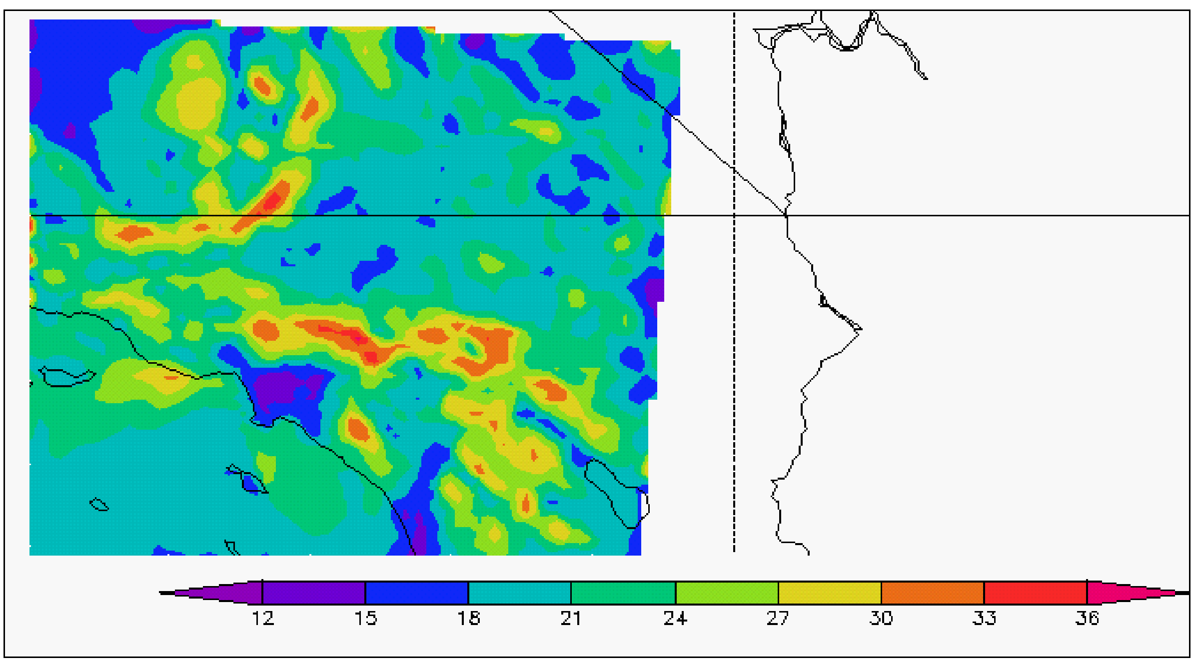

Figure 4-6 The simulated maximum 50-m AGL hourly-average wind speed (m/s) for the Southern California 5-km grid (Grid C) and the period July 2004 to June 2005, physics-based numerical forecast simulations using the MASS-6 atmospheric model.

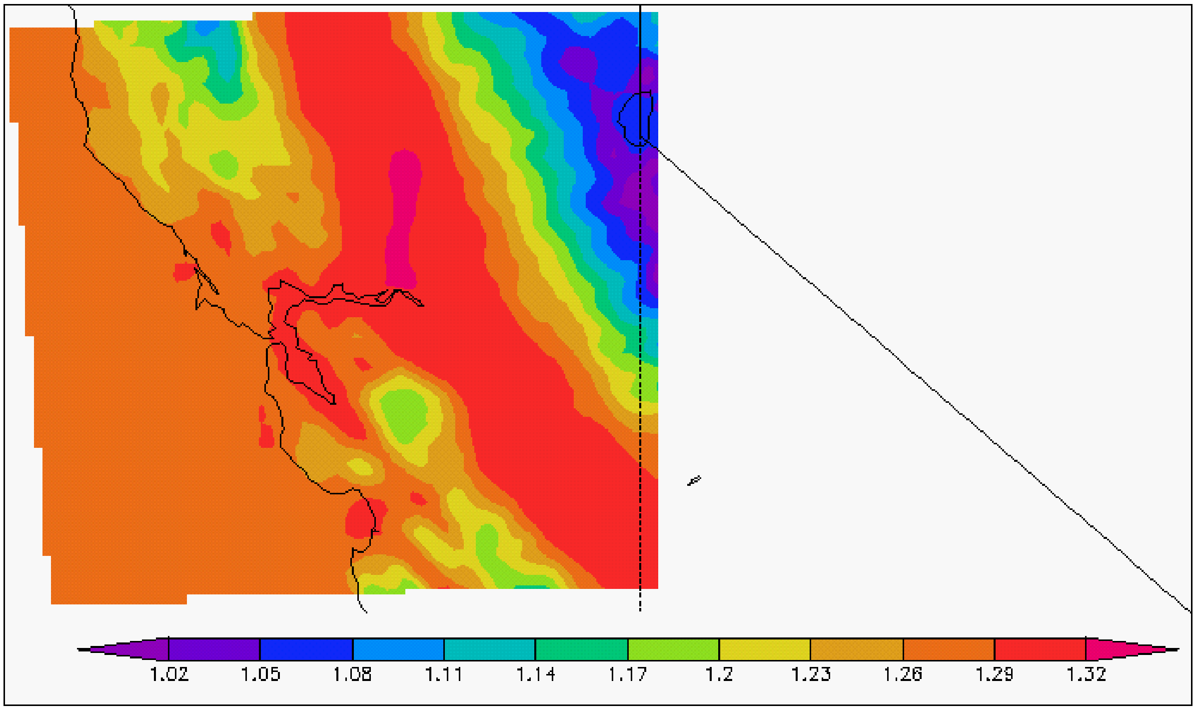

Figure 4-7 The simulated maximum 50-m AGL hourly-average air density (kg/m3) for the Northern California 5-km grid (Grid B) and the period July 2004 to June 2005, physics-based numerical forecast simulations using the MASS-6 atmospheric model.

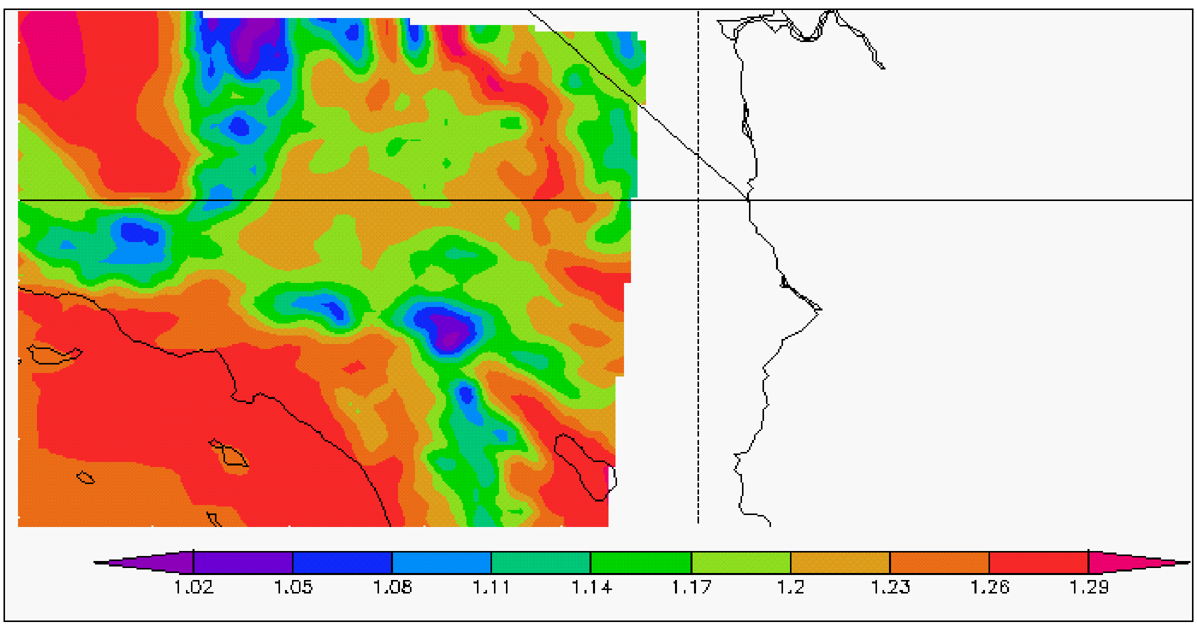

Figure 4-8 The simulated maximum 50-m AGL hourly-average air density (kg/m3) for the Southern California 5-km grid (Grid C) and the period July 2004 to June 2005, physics-based numerical forecast simulations using the MASS-6 atmospheric model.

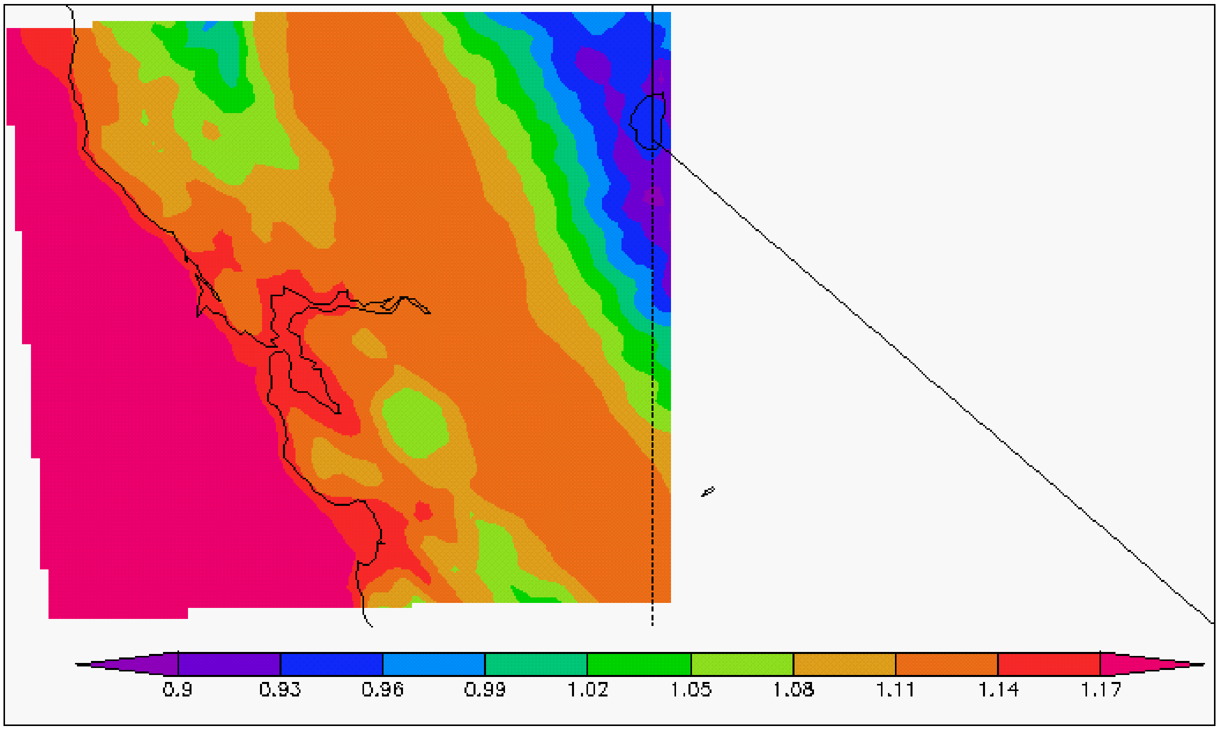

Figure 4-9 Simulated minimum 50-m AGL hourly average air density (kg/m3) for the Northern California 5-km grid (Grid B) and the period July 2004 to June 2005, physics-based numerical forecast simulations using the MASS-6 atmospheric model.

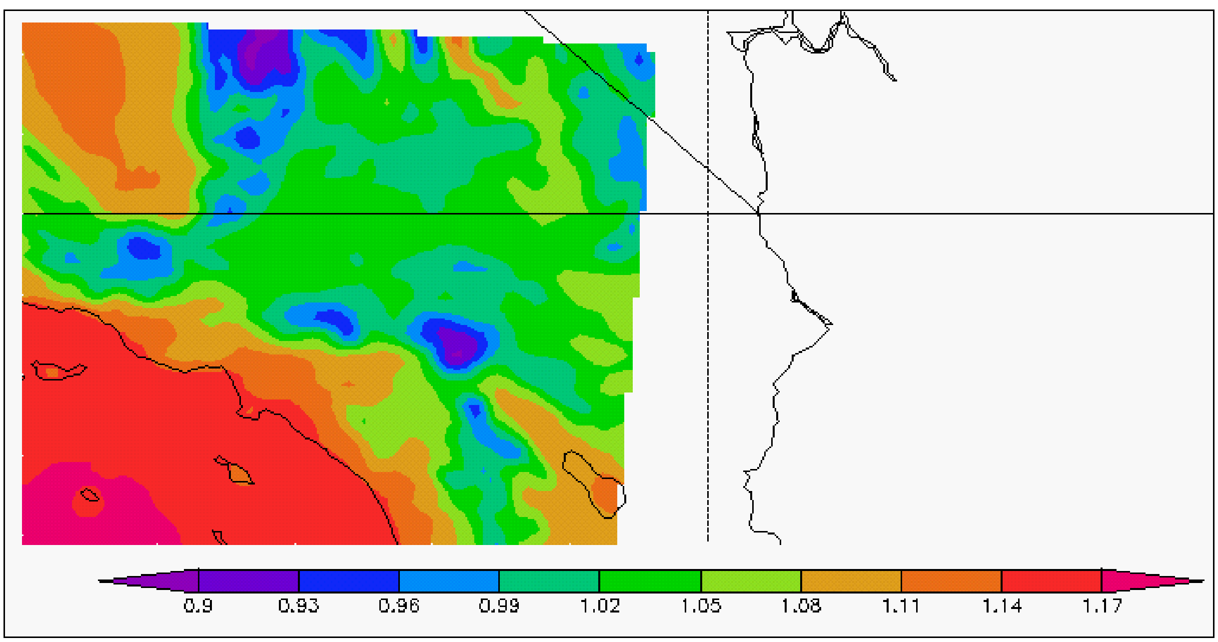

Figure 4-10 Simulated minimum 50-m AGL hourly-average air density (kg/m3) for the Southern California 5-km grid (Grid C) and the period July 2004 to June 2005, physics-based numerical forecast simulations using the MASS-6 atmospheric model.

5
DATA EXTRACTION PROGRAMS

This chapter describes the data extraction programs used to extract data from the CARD database. They include the **extract_pointstats** and **extract_timeseries** programs.

EXTRACT_POINTSTATS Program

This section provides an overview of the **extract_pointstats** program and provides detailed instructions on how to execute the program

Overview

The **extract_pointstats** program is designed to extract summary statistic grid point data for a user-selected period from a collection of summary statistic (ASTAT) files and to output grid point data for a list of grid points and variables based on user-selected settings in an option file.

The program is written in FORTRAN 90. The user needs to edit Makefile to configure it for the FORTRAN 90 compiler used by the computer system that will run the program. Currently, the "Makefile" is configured to utilize a Portland Group (pgf90) compiler running under the Linux operating system.

The user may select a specific location, defined by its latitude and longitude, at which to extract data from up to 64 of the nearest grid points to the latitude/longitude point. Table 5-1 lists the 152 summary statistic model variables that can be extracted at each specified location.

Table 5-1 Variables available to be extracted by the extract_pointstats program

Description	Units	Type	Level
10m Prev. Wind Direction	degrees	PREV	10 m
30 m Prev. Wind Direction	degrees	PREV	30 m
50 m Prev. Wind Direction	degrees	PREV	50 m
70 m Prev. Wind Direction	degrees	PREV	70 m
100 m Prev. Wind Direction	degrees	PREV	100 m
300 m Prev. Wind Direction	degrees	PREV	300 m
600 m Prev. Wind Direction	degrees	PREV	600 m
1000 m Prev. Wind Direction	degrees	PREV	1000 m
Mean 10m Wind Speed	m/s	MEAN	10 m
Mean 30 m Wind Speed	m/s	MEAN	30 m
Mean 50 m Wind Speed	m/s	MEAN	50 m

Mean 70 m Wind Speed	m/s	MEAN	70 m
Mean 100 m Wind Speed	m/s	MEAN	100 m
Mean 300 m Wind Speed	m/s	MEAN	300 m
Mean 600 m Wind Speed	m/s	MEAN	600 m
Mean 1000 m Wind Speed	m/s	MEAN	1000 m
STDEV 10m Wind Speed	m/s	STDEV	10 m
STDEV 30 m Wind Speed	m/s	STDEV	30 m
STDEV 50 m Wind Speed	m/s	STDEV	50 m
STDEV 70 m Wind Speed	m/s	STDEV	70 m
STDEV 100 m Wind Speed	m/s	STDEV	100 m
STDEV 300 m Wind Speed	m/s	STDEV	300 m
STDEV 600 m Wind Speed	m/s	STDEV	600 m
STDEV 1000 m Wind Speed	m/s	STDEV	1000 m
Max 10m Wind Speed	m/s	MAX	10 m
Max 30 m Wind Speed	m/s	MAX	30 m
Max 50 m Wind Speed	m/s	MAX	50 m
Max 70 m Wind Speed	m/s	MAX	70 m
Max 100 m Wind Speed	m/s	MAX	100 m
Max 300 m Wind Speed	m/s	MAX	300 m
Max 600 m Wind Speed	m/s	MAX	600 m
Max 1000 m Wind Speed	m/s	MAX	1000 m
Min 10m Wind Speed	m/s	MIN	10 m
Min 30 m Wind Speed	m/s	MIN	30 m
Min 50 m Wind Speed	m/s	MIN	50 m
Min 70 m Wind Speed	m/s	MIN	70 m
Min 100 m Wind Speed	m/s	MIN	100 m
Min 300 m Wind Speed	m/s	MIN	300 m
Min 600 m Wind Speed	m/s	MIN	600 m
Min 1000 m Wind Speed	m/s	MIN	1000 m
Mean 10m Air Density	kg/m**3	MEAN	10 m
Mean 30 m Air Density	kg/m**3	MEAN	30 m
Mean 50 m Air Density	kg/m**3	MEAN	50 m
Mean 70 m Air Density	kg/m**3	MEAN	70 m
Mean 100 m Air Density	kg/m**3	MEAN	100 m
Mean 300 m Air Density	kg/m**3	MEAN	300 m
Mean 600 m Air Density	kg/m**3	MEAN	600 m
Mean 1000 m Air Density	kg/m**3	MEAN	1000 m
STDEV 10m Air Density	kg/m**3	STDEV	10 m
STDEV 30 m Air Density	kg/m**3	STDEV	30 m
STDEV 50 m Air Density	kg/m**3	STDEV	50 m
STDEV 70 m Air Density	kg/m**3	STDEV	70 m
STDEV 100 m Air Density	kg/m**3	STDEV	100 m

STDEV 300 m Air Density	kg/m**3	STDEV	300 m
STDEV 600 m Air Density	kg/m**3	STDEV	600 m
STDEV 1000 m Air Density	kg/m**3	STDEV	1000 m
Max 10m Air Density	kg/m**3	MAX	10 m
Max 30 m Air Density	kg/m**3	MAX	30 m
Max 50 m Air Density	kg/m**3	MAX	50 m
Max 70 m Air Density	kg/m**3	MAX	70 m
Max 100 m Air Density	kg/m**3	MAX	100 m
Max 300 m Air Density	kg/m**3	MAX	300 m
Max 600 m Air Density	kg/m**3	MAX	600 m
Max 1000 m Air Density	kg/m**3	MAX	1000 m
Min 10m Air Density	kg/m**3	MIN	10 m
Min 30 m Air Density	kg/m**3	MIN	30 m
Min 50 m Air Density	kg/m**3	MIN	50 m
Min 70 m Air Density	kg/m**3	MIN	70 m
Min 100 m Air Density	kg/m**3	MIN	100 m
Min 300 m Air Density	kg/m**3	MIN	300 m
Min 600 m Air Density	kg/m**3	MIN	600 m
Min 1000 m Air Density	kg/m**3	MIN	1000 m
Mean 10m Temperature	C	MEAN	10 m
Mean 30 m Temperature	C	MEAN	30 m
Mean 50 m Temperature	C	MEAN	50 m
Mean 70 m Temperature	C	MEAN	70 m
Mean 100 m Temperature	C	MEAN	100 m
Mean 300 m Temperature	C	MEAN	300 m
Mean 600 m Temperature	C	MEAN	600 m
Mean 1000 m Temperature	C	MEAN	1000 m
STDEV 10m Temperature	C	STDEV	10 m
STDEV 30 m Temperature	C	STDEV	30 m
STDEV 50 m Temperature	C	STDEV	50 m
STDEV 70 m Temperature	C	STDEV	70 m
STDEV 100 m Temperature	C	STDEV	100 m
STDEV 300 m Temperature	C	STDEV	300 m
STDEV 600 m Temperature	C	STDEV	600 m
STDEV 1000 m Temperature	C	STDEV	1000 m
Max 10m Temperature	C	MAX	10 m
Max 30 m Temperature	C	MAX	30 m
Max 50 m Temperature	C	MAX	50 m
Max 70 m Temperature	C	MAX	70 m
Max 100 m Temperature	C	MAX	100 m
Max 300 m Temperature	C	MAX	300 m
Max 600 m Temperature	C	MAX	600 m

Max 1000 m Temperature	C	MAX	1000 m
Min 10m Temperature	C	MIN	10 m
Min 30 m Temperature	C	MIN	30 m
Min 50 m Temperature	C	MIN	50 m
Min 70 m Temperature	C	MIN	70 m
Min 100 m Temperature	C	MIN	100 m
Min 300 m Temperature	C	MIN	300 m
Min 600 m Temperature	C	MIN	600 m
Min 1000 m Temperature	C	MIN	1000 m
H2O Vapor Mixing Ratio	kg/kg	MEAN	10 m
H2O Vapor Mixing Ratio	kg/kg	MEAN	30 m
H2O Vapor Mixing Ratio	kg/kg	MEAN	50 m
H2O Vapor Mixing Ratio	kg/kg	MEAN	70 m
H2O Vapor Mixing Ratio	kg/kg	MEAN	100 m
H2O Vapor Mixing Ratio	kg/kg	MEAN	300 m
H2O Vapor Mixing Ratio	kg/kg	MEAN	600 m
H2O Vapor Mixing Ratio	kg/kg	MEAN	1000 m
H2O Vapor Mixing Ratio	kg/kg	STDEV	10 m
H2O Vapor Mixing Ratio	kg/kg	STDEV	30 m
H2O Vapor Mixing Ratio	kg/kg	STDEV	50 m
H2O Vapor Mixing Ratio	kg/kg	STDEV	70 m
H2O Vapor Mixing Ratio	kg/kg	STDEV	100 m
H2O Vapor Mixing Ratio	kg/kg	STDEV	300 m
H2O Vapor Mixing Ratio	kg/kg	STDEV	600 m
H2O Vapor Mixing Ratio	kg/kg	STDEV	1000 m
Max 10m H2O Vapor Mixing Ratio	kg/kg	MAX	10 m
H2O Vapor Mixing Ratio	kg/kg	MAX	30 m
H2O Vapor Mixing Ratio	kg/kg	MAX	50 m
H2O Vapor Mixing Ratio	kg/kg	MAX	70 m
H2O Vapor Mixing Ratio	kg/kg	MAX	100 m
H2O Vapor Mixing Ratio	kg/kg	MAX	300 m
H2O Vapor Mixing Ratio	kg/kg	MAX	600 m
H2O Vapor Mixing Ratio	kg/kg	MAX	1000 m
Min 10m H2O Vapor Mixing Ratio	kg/kg	MIN	10 m
H2O Vapor Mixing Ratio	kg/kg	MIN	30 m
H2O Vapor Mixing Ratio	kg/kg	MIN	50 m
H2O Vapor Mixing Ratio	kg/kg	MIN	70 m
H2O Vapor Mixing Ratio	kg/kg	MIN	100 m
H2O Vapor Mixing Ratio	kg/kg	MIN	300 m
H2O Vapor Mixing Ratio	kg/kg	MIN	600 m
H2O Vapor Mixing Ratio	kg/kg	MIN	1000 m
Wind Power Density	W/m**2	MEAN	30 m

Wind Power Density	W/m**2	MEAN	50 m
Wind Power Density	W/m**2	MEAN	70 m
Wind Power Density	W/m**2	MEAN	100 m
Wind Power Density	W/m**2	STDEV	30 m
Wind Power Density	W/m**2	STDEV	50 m
Wind Power Density	W/m**2	STDEV	70 m
Wind Power Density	W/m**2	STDEV	100 m
Max 30 m Wind Power Density	W/m**2	MAX	30 m
Max 50 m Wind Power Density	W/m**2	MAX	50 m
Max 70 m Wind Power Density	W/m**2	MAX	70 m
Max 100 m Wind Power Density	W/m**2	MAX	100 m
Min 30 m Wind Power Density	W/m**2	MIN	30 m
Min 50 m Wind Power Density	W/m**2	MIN	50 m
Min 70 m Wind Power Density	W/m**2	MIN	70 m
Min 100 m Wind Power Density	W/m**2	MIN	100 m

Execution Instructions

The user should set up the **extract_pointstats.opt** file before each **extract_pointstats** run. This option file allows the user to select (1) the locations at which data will be extracted. (2) how many grid points of data will be extracted for each location and (3) the number of model fields that will be extracted for each location.

Table 5-2 presents an example option file and describes the contents of each line. Once the option file has the desired settings, **extract_pointstats** can be executed.

Output from the **extract_pointstats** program is a comma-delimited (.csv) file. This file format is compatible with Microsoft Excel. Each output .csv file is identified by site id and uses the naming convention: $SITEID_stats.csv

The contents of the $SITEID_stats.csv file consist of a series of lines that contain the following fields:

1. Month of year or annual average.

2. I,J grid point within the model domain for the data.

3. Latitude/Longitude of the grid point.

4. Terrain height of the grid point.

5. Model variable data (up to all 152 summary statistic model variables) separated by commas.

Table 5-2 Example option file for the extract_pointstats program

```
0 H2O Vapor Mixing Ratio        kg/kg     MAX        600 m
0 H2O Vapor Mixing Ratio        kg/kg     MAX       1000 m
0 Min 10m H2O Vapor Mixing Ratiokg/kg     MIN         10 m
0 H2O Vapor Mixing Ratio        kg/kg     MIN         30 m
0 H2O Vapor Mixing Ratio        kg/kg     MIN         50 m
0 H2O Vapor Mixing Ratio        kg/kg     MIN         70 m
0 H2O Vapor Mixing Ratio        kg/kg     MIN        100 m
0 H2O Vapor Mixing Ratio        kg/kg     MIN        300 m
0 H2O Vapor Mixing Ratio        kg/kg     MIN        600 m
0 H2O Vapor Mixing Ratio        kg/kg     MIN       1000 m
0 Wind Power Density            W/m**2    MEAN        30 m
1 Wind Power Density            W/m**2    MEAN        50 m
0 Wind Power Density            W/m**2    MEAN        70 m
0 Wind Power Density            W/m**2    MEAN       100 m
0 Wind Power Density            W/m**2    STDEV       30 m
1 Wind Power Density            W/m**2    STDEV       50 m
0 Wind Power Density            W/m**2    STDEV       70 m
0 Wind Power Density            W/m**2    STDEV      100 m
0 Max    30 m Wind Power DensityW/m**2    MAX         30 m
1 Max    50 m Wind Power DensityW/m**2    MAX         50 m
0 Max    70 m Wind Power DensityW/m**2    MAX         70 m
0 Max   100 m Wind Power DensityW/m**2    MAX        100 m
0 Min    30 m Wind Power DensityW/m**2    MIN         30 m
1 Min    50 m Wind Power DensityW/m**2    MIN         50 m
0 Min    70 m Wind Power DensityW/m**2    MIN         70 m
0 Min   100 m Wind Power DensityW/m**2    MIN        100 m
```

Key

1 - Input directory path for model data

2 - Output directory path of comma delimited data

3 - Start month to process

4 - End month to process

5 - Set to "annual" to process annual stats.

6 - GRID.REGION tag for the model data

7 - Number of site locations to extract

8 - For each location: three-letter site ID, Latitude, Longitude and number of closest grid points to extract. Make sure the data format is correct. Format should be:

XXX FFFFF.FFFF FFFFF.FFFF II

Where **XXX** is the three-letter site ID, **FFFFF.FFFF** are the latitude and longitude coordinates, and **II** is the number of closest grid points.

9 - Number of summary statistic model variables (set at 152 for the CARD database)

10 - List of each summary statistic model variable by: on/off switch, variable name, variable units, variable type, and variable level. The on/off switch should be set to 1 to extract the variable and 0 to ignore the variable. Variable levels, names, types, and units are for informational purposes and are not adjustable.

EXTRACT_TIMESERIES Program

This section provides an overview of the **extract_timeseries** program and provides detailed instructions on how to run the program.

Overview

The **extract_timeseries** program is designed to extract grid point data for a user-selected period from an annual collection of hourly model plot file data and output data for a list of grid points and variables based on selections set by the user in an option file. The program is written in FORTRAN 90. The user needs to edit “Makefile” that is provided with the source code to configure it for the FORTRAN 90 compiler that is to be used on the computer system that will run the program. Currently, “Makefile” is configured to utilize a Portland Group (pgf90) compiler running under the Linux operating system.

The user may select a location, defined by latitude and longitude, at which to extract data from up to 64 of the nearest grid points to the selected point. The user may select any of the 44 database variables listed in Table 5-3 for extraction at each specified location.

Execution Instructions

Extract_timeseries expects all the model data to be in dated directories underneath a REGION/GRID directory. The user should set the **extract_timeseries.opt** file before each **extract_timeseries** run. This option file allows the user to select which locations to extract data for, how many grid points of data to extract for each location, and the number of model fields to extract for each location.

Table 5-3 presents an example option file and describes the contents of each line. Once the option file has the desired settings, **extract_timeseries** can be executed. Each output .csv file is identified by site i.d., start date/hour and end date/hour. Output from the **extract_timeseries** program is a comma-delimited (.csv) file that is compatible with Microsoft Excel. The contents of the .csv file is a series of lines that each contain the following comma-delimited fields:

1. Local date/time.

2. I,J grid point within the model domain for the data.

3. Latitude/Longitude of the grid point.

4. Terrain height for the grid point.

5. Model variable data (up to all 44 model variables) separated by commas.

Table 5-3 : Variables available to be extracted by extract_timeseries program

Description	Level	Units
Earth Relative Wind Speed	10 m	m/s
Earth Relative Wind Speed	30 m	m/s
Earth Relative Wind Speed	50 m	m/s
Earth Relative Wind Speed	70 m	m/s
Earth Relative Wind Speed	100 m	m/s
Earth Relative Wind Speed	300 m	m/s
Earth Relative Wind Speed	600 m	m/s
Earth Relative Wind Speed	1000 m	m/s
Earth Relative Wind Direction	10 m	deg
Earth Relative Wind Direction	30 m	deg
Earth Relative Wind Direction	50 m	deg
Earth Relative Wind Direction	70 m	deg
Earth Relative Wind Direction	100 m	deg
Earth Relative Wind Direction	300 m	deg
Earth Relative Wind Direction	600 m	deg
Earth Relative Wind Direction	1000 m	deg
Air Density	10 m	kg/m**3
Air Density	30 m	kg/m**3
Air Density	50 m	kg/m**3
Air Density	70 m	kg/m**3
Air Density	100 m	kg/m**3
Air Density	300 m	kg/m**3
Air Density	600 m	kg/m**3
Air Density	1000 m	kg/m**3
Temperature	10 m	C
Temperature	30 m	C
Temperature	50 m	C
Temperature	70 m	C
Temperature	100 m	C
Temperature	300 m	C
Temperature	600 m	C
Temperature	1000 m	C
H2O Vapor Mixing Ratio	10 m	kg/kg
H2O Vapor Mixing Ratio	30 m	kg/kg
H2O Vapor Mixing Ratio	50 m	kg/kg

H2O Vapor Mixing Ratio	70 m	kg/kg
H2O Vapor Mixing Ratio	100 m	kg/kg
H2O Vapor Mixing Ratio	300 m	kg/kg
H2O Vapor Mixing Ratio	600 m	kg/kg
H2O Vapor Mixing Ratio	1000 m	kg/kg
Wind Power Density	30 m	W/m**2
Wind Power Density	50 m	W/m**2
Wind Power Density	70 m	W/m**2
Wind Power Density	100 m	W/m**2

Table 5-4 Example option file for the extract_timeseries program

```
/inpath/                                                           -  1
/outpath/                                                          -  2
2005062901                                                         -  3
2005063000                                                         -  4
8                                                                  -  5
C.CALR1                                                            -  6
2                                                                  -  7
OAK    35.0342  -118.3597 1                                        -  8
MV1    33.909   -116.6294 1
44                                                                 -  9
0    10 m   Earth Relative Wind Speed     m/s             ( 1)  - 10
0    30 m   Earth Relative Wind Speed     m/s             ( 2)
1    50 m   Earth Relative Wind Speed     m/s             ( 3)
0    70 m   Earth Relative Wind Speed     m/s             ( 4)
0   100 m   Earth Relative Wind Speed     m/s             ( 5)
0   300 m   Earth Relative Wind Speed     m/s             ( 6)
0   600 m   Earth Relative Wind Speed     m/s             ( 7)
0  1000 m   Earth Relative Wind Speed     m/s             ( 8)
0    10 m   Earth Relative Wind Direction deg             ( 9)
0    30 m   Earth Relative Wind Direction deg             (10)
0    50 m   Earth Relative Wind Direction deg             (11)
0    70 m   Earth Relative Wind Direction deg             (12)
0   100 m   Earth Relative Wind Direction deg             (13)
0   300 m   Earth Relative Wind Direction deg             (14)
0   600 m   Earth Relative Wind Direction deg             (15)
0  1000 m   Earth Relative Wind Direction deg             (16)
0    10 m   Air Density                   kg/m**3         (17)
0    30 m   Air Density                   kg/m**3         (18)
0    50 m   Air Density                   kg/m**3         (19)
0    70 m   Air Density                   kg/m**3         (20)
0   100 m   Air Density                   kg/m**3         (21)
0   300 m   Air Density                   kg/m**3         (22)
0   600 m   Air Density                   kg/m**3         (23)
0  1000 m   Air Density                   kg/m**3         (24)
0    10 m   Temperature                   C               (25)
0    30 m   Temperature                   C               (26)
0    50 m   Temperature                   C               (27)
0    70 m   Temperature                   C               (28)
0   100 m   Temperature                   C               (29)
0   300 m   Temperature                   C               (30)
0   600 m   Temperature                   C               (31)
0  1000 m   Temperature                   C               (32)
0    10 m   H2O Vapor Mixing Ratio        kg/kg           (33)
0    30 m   H2O Vapor Mixing Ratio        kg/kg           (34)
0    50 m   H2O Vapor Mixing Ratio        kg/kg           (35)
0    70 m   H2O Vapor Mixing Ratio        kg/kg           (36)
0   100 m   H2O Vapor Mixing Ratio        kg/kg           (37)
0   300 m   H2O Vapor Mixing Ratio        kg/kg           (38)
0   600 m   H2O Vapor Mixing Ratio        kg/kg           (39)
0  1000 m   H2O Vapor Mixing Ratio        kg/kg           (40)
0    30 m   Wind Power Density            W/m**2          (41)
1    50 m   Wind Power Density            W/m**2          (42)
0    70 m   Wind Power Density            W/m**2          (43)
0   100 m   Wind Power Density            W/m**2          (44)
```

Key

1 - Input directory path for model data

2 - Output directory path of comma delimited data

3 - Start date/hour to process in local standard time

4 - End date/hour to process in local standard time

5 - Time shift from local time to UTC. 8 hours for PST.

6 - GRID.REGION tag for the model data

7 - Number of site locations to extract

8 - For each location: three-letter site ID, Latitude, Longitude and number of closest grid points to extract. Make sure the data format is correct. Format should be:

XXX FFFFF.FFFF FFFFF.FFFF II

where **XXX** is the three-letter site ID, **FFFFF.FFFF** are the latitude and then longitude and **II** is the number of closest grid points.

9 - Number of model variables (set at 44 for the CARD database)

10 - List of each model variable by: on/off switch, variable level, variable name, variable units and variable count. The on/off switch should be set to 1 to extract the variable and 0 to ignore the variable. Variable levels, names, and units are for informational purposes and are not adjustable.

6
SUMMARY

The *California Wind Generation Research Dataset* (CARD) contains one continuous year of hourly grid point data for a set of meteorological variables. The data are provided at multiple levels on two horizontal grids, each with a grid cell size of 5 km, one located in Northern California and one in Southern California. The dataset was generated for the period July 1, 2004, through June 30, 2005, using the MASS 6 meso-scale model, and it is not based directly on measured data.

The database variables are wind direction (degrees), wind speed (m/s), air density(kg/m^2) , temperature (C), water vapor mixing ratio (kg/kg) at height levels of 10, 30, 50, 70, 100, 300, 600 and 1000 meters above ground level and the wind power density at 10, 30, 50, and 70 meters above ground level.

The summary statistics included in the database should not be considered to be representative of long-term mean conditions at the grid points as they are generated from data for only one year, which may not be representative. Additionally the statistics are generated from raw model data and may not account for small-scale terrain features. The database does not constitute a wind map or climatology.

The CARD database can be used to simulate the hourly operation of a wind project at candidate sites, test wind energy forecasting methods, and conduct other wind power research and planning activities.

7 REFERENCES

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